Assessing the Impact of Payment Card Fee Regulation*

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Abstract

We analyze the effects of a hypothetical payment card fee regulation on bank profits, consumer welfare, and merchant welfare. We model consumers' and merchants' bank choices for debit card services, cardholders' demand for card usage (conditional on bank choice), and how banks account for these in setting card fees to their customers. To estimate the model, we use bank-level data and survey data from the Norwegian debit card scheme, BankAxept. We conduct counterfactual exercises to analyze the effects of interchange fee regulations in the debit card scheme.

Keywords: Debit cards, merchants and consumers bank choices, card fee regulation
JEL Codes: G21, C13, L11, L51

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1 Introduction

Many countries subject the payment card industry to various price regulations, mostly aiming to protect merchants from excessive commissions. Australia, Canada, Singapore, Switzerland, Mexico, Chile and Denmark impose cap regulations on interchange fees (IFs). These are fees paid by the merchant's bank to the cardholder's bank for every card transaction. The UK, Sweden, and Brazil regulate card networks' rules and agreements to either reduce merchant fees or outlaw them.[1] In 2011 the US Fed approved a cap regulation on consumer debit card IFs, resulting in a 48% cut in IF payments.[2] In March 2015 the EC adopted a cap regulation on both cross-border and domestic IFs in the EU/EEA.[3] Norway implemented the EU/EEA IF regulation in 2016.

In the US some banks reacted to the IF cap regulation by increasing significantly fees to consumers. This has led to policy makers' concerns that such price regulations could make consumers worse off (Hayashi, 2012). To correctly assess the welfare effects of a payment card fee regulation one must take into account consumer preferences between different payment methods, merchants demand and banks' non-trivial pricing incentives.

We propose and estimate a structural model of a debit card system that allows us to assess how banks would react to a (hypothetical) card fee regulation and what the resulting effect would be on consumer and merchant welfare. Our model captures the key features of the industry: consumers and merchants choose their banks to obtain debit card services, cardholders decide whether to pay by card at points of sale, and banks collect fees from their customers. We thereby allow banks to account for the interaction between consumers and merchants in setting fees to their customers. A bank can be an "issuer" of debit cards or an "acquirer" of merchants that accept debit cards, or both. Hence, banks can collect fees from their cardholders, in the form of a membership fee and a transaction fee for debit card transactions, while collecting fees from their merchants for membership and debit card transactions they process.

Using our demand-side estimates and cost parameters recovered from supply-side conditions, we plan to address our policy questions via counterfactual exercises. Our data come from the Norwegian debit card scheme, BankAxept (BAX), where IFs are set zero. We plan to assess the impact of three types of hypothetical fee regulations in the BAX scheme: 1)

[1]See Weiner and Wright (2005), EFTA Surveillance Authority (2005), European Competition Commission (2007), Norges Bank (2009) and Norges Bank (2010). The European Commission (EC) forced MasterCard to cut its cross-border IFs to near zero (ten-year long case: COMP/34.579) and Visa to cap its intra-EEA credit and debit card IFs (six-year long case: COMP/39.398).

[2]See http://www.federalreserve.gov/paymentsystems/regii-average-interchange-fee.htm

[3]The regulation caps IFs at 0.2% of the transaction value for consumer debit cards and at 0.3% for consumer credit cards. See http://ec.europa.eu/competition/publications/cpb/2015/003_en.pdf

introducing a positive IF at the average EU Visa debit card IFs, paid by the acquirer to the issuer for every card transaction, 2) introducing an IF that maximizes consumer and merchant welfare, and 3) introducing an IF that sets equilibrium issuer side fees to zero to quantify the lower bound of IFs that lead to consumer rewards for card usage. All IF counterfactuals are implemented by decreasing the marginal cost of issuer banks and increasing the marginal cost of acquirer banks by the amount of the introduced IF. Our main contribution is providing a tool for ex-ante evaluation of payment card fee regulation, given information regulators typically hold.

BankAxept (BAX) is the most intensively used payment method in Norway, accounts for 84% of all card payments in 2009 (Norges Bank, 2009) and 80% of consumer deposit value in our sample period (2006-2009). It is a mature debit card scheme where almost all consumers have at least one BAX card and almost all merchants accept BAX cards. Most Norwegian banks are members of the scheme both as card issuers to consumers and acquirers of merchants. In the BAX system, during our sample period, consumers mostly pay positive card transaction fees, whereas in most credit and debit card schemes consumers are subsidized by negative fees (rewards) per card transaction or they pay zero fees. Positive card transaction fees to consumers allow us to estimate price elasticities of card usage demand, which has not been feasible in previous empirical studies of payment card markets (see below our summary of the literature).

Our data consist of 24 major banks over four years (2006-2009) and 19 counties in Norway. We have annual bank-county-level information on the value of consumer deposit accounts, the volume and value of BAX card transactions, the number of BAX card acceptance agreements with merchants, branch network, interest rates on deposits, interest rates on loans, and various fees paid by consumers and merchants. We also have county-level demographic statistics from Statistics Norway and household-level survey data that provide payment choices (card, cash, etc.) that a representative set of (2,608) households made at each transaction over one week in September 2007.[4]

We model consumers' issuer bank choice as a function of their net expected benefit of using the debit card in addition to other demand factors such as card fees, branch network, and other bank and market characteristics. Conditional on bank choice, we model cardholders' payment method choice at point-of-sales based on the card usage fee, branch network, and other bank and market characteristics. We allow consumers to differ in their demand sensitivity to card fees. The two-stage decision-making on the consumer side captures the

[4]Norges Bank conducted the survey. The survey data do not provide information on which bank each respondent has a deposit account/debit card at. See Gresvik and Haare (2008) for a detailed description of the survey data.

fact that consumers' bank demand sensitivity to card usage fees depends on how frequently consumers expect to use their cards. Estimating card usage conditional on bank choice accounts for consumers' self-selection to banks based on their bank demand sensitivity to annual card fee and corrects for this selection in their choice of card usage.

We model merchants' acquirer bank choice as a function of banks' merchant fees, branch network, and other bank and market characteristics. There are two important market practices: Acquirers charge non-linear (two-part tariff) merchant fees and merchants must accept their customers' choice of payment methods. To rationalize observed two-part tariff merchant fees in banks' optimal pricing conditions, we introduce merchant heterogeneity in the volume of BAX transactions. Intuitively, if merchants were homogenous, banks would be indifferent between any level of transaction and fixed merchant fee as long as the average merchant fee at a given debit card transaction volume is constant. This is because merchants decide only whether to choose one acquirer bank or another at a given card transaction volume determined by cardholders' point-of-sale payment choices. Hence, for merchants' bank choices only the average merchant fee matters. We allow for two types of merchants based on their volume of BAX transactions to identify two-part tariff merchant fees in banks' optimal pricing: banks price discriminate between large and small merchants using volume discounts, and so different merchant types will face different average merchant fees, even if their fixed and transaction fees are the same. We do not have data on merchant type-specific market shares of banks. To overcome this problem we complement the bank-level data with data on the number of merchant types from Statistics Norway and the survey data showing the type of merchant processing each transaction. Using these complementary data we calculate the average volume of BAX card transactions processed by each merchant type and identify merchant type-specific market shares of acquirer banks.

We employ the generalized method of moments to estimate cardholders' demand for debit card usage (conditional on bank choice), consumers' bank choice demand for a deposit account (or debit card issuing), and merchants' bank choice demand for BAX card acceptance services. We take into account price endogeneity driven by unobservable debit card and bank characteristics, which are likely correlated with equilibrium fees. Market-specific variable cost measures (such as wage per employee, rent per branch, transmission costs per BAX card transaction) as well as Berry, Levinsohn, and Pakes (1995) type instruments on the number of branches provide cost-side instruments. Bank and market (county-year) fixed effects control for time-invariant unobserved characteristics. Covariation between card usage shares, deposit accounts shares, the BAX transaction and annual fees across markets and banks identifies the coefficient of the BAX transaction and annual fee. To improve identification of consumers' sensitivity to fees we make use of market-specific income distributions in modeling consumer heterogeneity.

Our results on the consumer side show that holding a debit card generates significant benefits to consumers. In particular, we estimate the average convenience benefit of paying by debit card rather than any other method (conditional on bank choice) to be 0.51 NOK (which is 5.4 Euro cents) per card transaction. We also find that consumers' bank demand is elastic with respect to annual card fee (with an elasticity of -1.15) and inelastic with respect to card transaction fee (with an elasticity of -0.95). Furthermore, debit card usage demand is elastic with respect to the card usage fee (with elasticity of -2.31) as well as with respect to annual card fee (with elasticity of -5.85). These results have important implications for our counterfactual exercises. For instance, as a reaction to an introduction of an interchange fee to the debit system, an issuer bank decreases its card usage fee for consumers since the interchange fee reduces its effective cost of card transactions. When consumers' card usage demand is elastic, this reduction of card usage fee would be large and so the introduction of the interchange fee would benefit consumers more. Including the income distribution as an observable measure of consumer heterogeneity and interacting it with the coefficient on transaction fees further shows that high-income consumers are less elastic to fees than low-income consumers.

We find that merchants' bank choice is significantly and negatively affected by merchant fees. High-volume merchants' acquirer demand is more elastic to transaction merchant fee (with an elasticity of -2.36) than small-volume merchants' bank choice demand (with an elasticity of -0.13) . To improve the precision of estimated merchant side demand parameters we propose an identification strategy that exploits the supply-side equilibrium model as follows. The volume of card transactions at both merchant types is a function of issuer-side card transaction fees. Merchants process more (less) card transactions when consumers face lower (higher) card transaction fees in their market. The extent of this reaction depends on two components: the issuer bank's market share and merchant type because large merchants obtain a larger share of changes in total card transactions. As the average acquirer-side card transaction volume varies in issuer-side card transaction fees, so do different merchant types' average fees, even if banks keep nonlinear prices to merchants fixed. This link between issuer- and acquirer-side fees places restrictions on the equilibrium acquirer-side fees. We construct supply-side moment conditions from the first-order conditions of the banks' pricing problem to exploit this link between the consumer side and merchant side to identify merchant side parameters, leveraging consumer side card fee variation. The results of this analysis are in preparation.

1.1 The related literature

The early literature on the theory of interchange fees in particular and two-sided markets in general conclude that the relationship between the socially and privately optimal price allocation between consumers and merchants (and so, interchange fee) depends on quantitative considerations.[5] Assessing distortions of the price structure requires a significant amount of information, and in principle an optimal intervention could go in either direction. Recent work however has documented some reasons for why payment platforms' profitable pricing strategies would indeed lead to inefficiently high merchant fees (or interchange fees).[6] A common finding of the theoretical literature is that the socially optimal price allocation between merchants and consumers (and so the socially optimal interchange fee level) depends on the average surpluses of consumers and merchants from a card transaction, and the demand elasticities of consumer and merchant demands. Our paper is the first attempt to measure these empirically and to provide a methodology that will enable policy makers to determine the socially optimal interchange fee level before implementing any regulation.

Empirical studies on the payment card industry have developed very recently and analyzed mainly the determinants of consumers' choices of payment instruments at point-of-sales (See, for instance, Rysman (2007); Klee (2008); Borzekowski et al. (2008); Koulayev et al. (2016); Cohen and Rysman (2013)), how these choices are affected by reward programs (Ching and Hayashi, 2010) or by allowing merchants to surcharge card payments (Bolt et al., 2010). These studies mostly use survey data which do not provide information on the exact fees that consumers pay when they use different payment cards. Thus, they cannot identify the price sensitivity of consumers' demand for bank and for payment card usage. Besides they lack data on merchants' demand for banks and banks' merchant fees, so they cannot identify the price sensitivity of merchants' demand for bank. As a result, they cannot address the question of how banks would react to a payment card fee regulation. Our unique data and modelling approach enable us to address these questions.

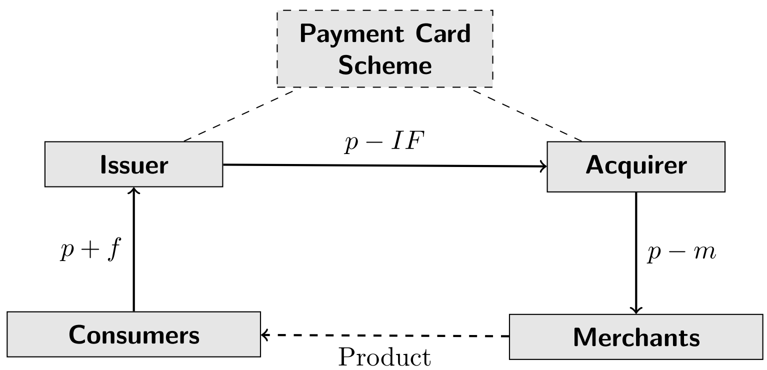
[5] See the interchange fee literature, e.g., Schmalensee (2002), Wright (2004), or reviews by Evans and Schmalensee (2005), Verdier (2011) and Chakravorti (2010).The two-sided market literature was pioneered by Caillaud and Jullien (2003), Rochet and Tirole (2003, 2006), Armstrong (2006) and, more recently, Weyl (2010).

[6] Rochet and Tirole (2002), Wright (2012) explain this by merchant internalization: competing merchants accept cost-increasing cards as a way to steal customers from their rivals. Guthrie and Wright (2007) and Armstrong (2006) link this bias against merchants to platform competition: If merchants accept the cards of multiple card networks (multi-home), platforms try to woo cardholders back from their rivals by lowering their prices, but set monopoly prices to merchants in exchange for providing access to their exclusive turf of cardholders. Bedre-Defolie and Calvano (2013) explain another source of bias against merchants by the fact that the payment network internalizes consumers' card usage surplus (via using non-linear pricing), but does not account for merchants' surplus from card usage (given that affiliated merchants cannot refuse cards or cannot surcharge card payments without cost).

2 Payment Card Schemes and BankAxept

Figure 1 shows money transfers (bold arrows) and data/product exchange (dashed lines) within a payment scheme for each payment card transaction. In most payment card schemes every time a cardholder purchases a good by card, she pays a transaction fee (f) to her bank ("issuer") and the merchant pays a transaction fee, also known as "merchant fee" or "merchant discount", (m) to her bank ("acquirer"), and the acquirer pays a transaction fee, also known as "interchange fee (IF)", to the issuer. The issuer transfers the price of the product (p) from the cardholder's account to the acquirer, which in turn transfers the amount to the merchant's account. Both issuer and acquirer banks need to be members of the card scheme in order to have the ability to process payments by the scheme's cards. The card scheme sets the rules, authorizes and exchanges data to settle each card transaction between the issuer of the card and the acquirer of the merchant.

Figure 1: Transfers within a payment card scheme.



We focus on the national debit card scheme in Norway (BankAxept or BAX). BAX cards are the most intensively used payment cards in Norway. In 2009, BAX covered 84% of all card payments in Norway (Norges Bank, 2010). Most BAX cards also have an alternative payment solution. BAX combination cards only exist with VISA and MasterCard, and the vast majority of the combined cards come with a Visa function. However, BAX is the default payment option at POS terminals in Norway unless the cardholder opts for a different payment solution attached to her card. Hence, during our sample period (2006-2009), at a POS the main alternative payment method to BAX cards was cash.

Most Norwegian banks are members of the BAX scheme both as an issuer of BAX cards providing card payment services to cardholders and as an acquirer of merchants providing BAX card acceptance services. Each member bank must obey the scheme's general rules,[7]

[7]During our sample period, the BAX system was jointly owned by Norwegian Financial Service Association (FNH) and the Norwegian Savings Bank Association (SPF), and was operated by the Norwegian Banks'

but operates independently of each other: The issuer and acquirer banks of the scheme set their BAX fees non-cooperatively.

Like any debit card, consumers can get a BAX card only from an issuer bank where they hold a deposit account. Opening or holding a deposit account in Norway is free and consumers on average hold one or two deposit accounts (Gresvik and Haare, 2008). On the other hand, consumers usually have only one deposit account where they receive their salary, and so, which they use for daily consumption and name as their main account. This is the deposit account that consumers have a debit (BAX) card from. During our sample period (2006-2009), to hold a BAX card consumers generally needed to pay an annual fee to their bank and cardholders paid a transaction fee to their bank each time they settled a POS transaction by BAX card.

To accept BAX payments merchants need to have a merchant agreement with an acquirer bank. During our sample period, merchants generally paid a one-time fee to register a BAX terminal at their location and a monthly settlement fee to their bank. In addition, merchants paid a transaction fee to their bank for each BAX card transaction settled at their POSs.

Banks set prices and interest rates at the national level (national pricing). As most transactions are electronic and the cost of a electronic transaction is the same regardless of which county it is processed in, there is no cost-related reason to set different prices across counties. Yet, the banks could still set different prices to exploit regional demand. According to staffs at Norges Bank, the main reason for setting prices at a national level is a political reason. Norway is a egalitarian country, so it would be "politically difficult" to have different prices across counties because this might result in a market share loss due to negative public relations.

Similar to some other domestic debit card schemes in the EU25, like in Denmark, Netherlands, and Finland, the BAX system does not apply an interchange fee (IF), which is a fee paid by the acquirer to the issuer for each card transaction in most credit card schemes and international debit card schemes, like Visa or MasterCard.[8] The BAX system has a lower degree of acquirer concentration than the EU25 average.[9] Merchant fee levels of the BAX scheme are significantly lower than the prevailing levels for other card schemes.[10] On the

Payment and Clearing House (BBS). BAX system rules were set jointly by the member banks of FNH and SPF. See BAX Rules in EFTA Surveillance Authority (2005).The BAX system is now a stock-based company owned by the Norwegian banks and operated mainly by Nets (formerly BBS). Its rules are now set within the BAX company.

[8]In earlier times, there was an interchange fee (IF) in the BAX system. It was paid from the issuer to the acquirer (so a negative IF in Figure 1). The purpose of the IF was to balance the income of the issuer and acquirer, and the negative IF payment reflects historically low merchant fees and high consumer fees in the BAX system.

[9]See European Competition Commission (2007) and Eurocard-MasterCard Decision COMP/34.579.

[10]Each time a consumer checks out by BAX card, the merchant pays a fee around NOK 0.12-0.20. In a

other hand, issuance fees and annual card fees charged to cardholders in Norway tend to be higher than the EU25 average. Finally, card transaction fees to consumers were widely used in the BAX system during our sample period, whereas consumers do not pay per-transaction card fees in most European or international card schemes. If anything, consumers benefit from rewards, like miles, cash backs, if they pay by card.

3 Data

We use a panel data set of the 24 major banks providing issuing and acquiring services in the national debit card scheme in Norway, BankAxept (BAX), which contains annual market share, price and cost information at the bank level for the 19 counties of Norway over four years (2006-2009).[11] We collected the data from several sources. From Statistics Norway (SSB), we obtained banks' BAX card fees for consumers and for merchants. From questionnaires addressed to the banks,[12] we obtained banks' BAX cardholder market shares. BBS (now named as Nets) provided acquirer banks' market shares of merchant locations with BAX card agreements, as well as issuer and acquirer banks' card usage market shares measured in volume and value at point of sales in Norway. From Finance Norway, the financial industry organization, we observe banks' numbers of branch offices in all counties. From ORBOF Statistics of Norges Bank, we collected data on the banks' deposit account values, interest rates on loans and deposit accounts, as well as banks' cost information such as rent and wage expenses, total numbers of employees, and payment transmission costs. Finally, we make use of transaction information from an individual-level payment habits survey conducted by Norges Bank.

3.1 Issuing Market

All banks in our sample issue BAX cards and provide general payment services to consumers. In the Norges Bank questionnaire of issuer banks, 12 out of the 24 banks delivered data on their total number of BAX customers. Six of these provided data on the distribution of BAX customers across counties. The data on the market shares in deposit account value of the 24 issuer banks represent around 80% of the total value on deposit accounts in Norway. We find that for each bank for which we have complete data, the pairwise correlation between county-level market shares based on the number of BAX customers and the shares based on

Visa or MasterCard scheme, the merchant fee is around 1.5-3% of the transaction value.

[11] We exclude Svalbard, a remote and sparsely populated island, from the sample.

[12] Financial Infrastructure Unit of the Financial Stability Department at Norges Bank sent out the questionnaires to banks and collected their answers. Data of individual banks are not revealed.

deposit account values is around 99%. We henceforth assume that the distribution of BAX customers of issuer banks across counties is the same as the distribution of deposit account values of banks across counties.

Table 1: Issuer side summary statistics

Issuer variables, $N = 1824$	**mean**	**sd**	**max**	**min**	**median**
value_deposit (million NOK)	1,142.36	4172.47	56,594.06	0	18.70
bax_trans (millions)	1.32	4.23	57.82	3.56E-4	0.07
bax_value (million NOK)	528.44	1,740.20	21,410.00	0.09	24.21
annual_fee (NOK)	246.6	27.7	300	150	250
trans_fee (NOK)	2.1	0.8	4	0	2
interest_deposit (%)	3.2	1.2	5.3	1.5	2.9
interest_loan (%)	5.5	1.2	7.6	3.9	5.1
branch	2	6	57	0	0

Table 1 shows summary statistics of our issuer side data.[13] Banks are substantially asymmetric in terms of the value on deposit accounts and BAX transactions.[14] The standard deviation is larger than the mean for these variables and the standard deviation across the banks is about 2.5 times larger than the standard deviation across the counties (2400 vs. 900). However, no single bank dominates in all counties. Instead, ten banks have dominance in at least one county. A variation over time is the smallest but the standard deviation across years is still over 100.

Due to national pricing practice of banks, the BAX card prices (annual_fee and trans_fee) as well as the deposit and loan interest rates in Table 1 do not vary across the counties. Their standard deviation reflects differences across the banks and changes over time. As in the deposit value and the BAX transactions, variations across the banks are much larger than variations across time, but the overall variation is much smaller than that of the deposit value and the BAX transactions. The banks' national pricing practice combined with the relatively small overall variation imposes a challenge in estimating the "price" elasticity of the deposit value and BAX transactions. The table also shows the summary statistics for the number of branch offices that the banks have in each county. The mean number is 2 and the median number is 0, implying that the banks do not have branches in all counties and focus on counties they have large customer bases. The mean number of branches conditional on having a branch is 8.39.

[13]We need to impute values for a small number of observations for which information is missing. We explain in detail the assumptions and procedures used in Appendix A.1.

[14]The BAX transaction variables are highly correlated with the deposit value with the pairwise correlation close to 0.98 for bax_trans and over 0.98 for bax_value.

We report the summary statistics on banks' costs of wages per employee, rent per branch and total transmission fees per BAX card transactions in Table 10, in Appendix D.1. Transmission fees are paid to other banks for various payment transmissions, including BAX. In Appendix D.1 the hedonic regressions of BAX transaction fees on bank characteristics show that, while much of the variation in annual card fees is explained by unobserved bank-level heterogeneity, cost variables (and to some extent banks' branch networks) are the main drivers of these fees.

3.2 Acquiring market

In our sample, 23 (out of the 24) banks provide BAX card acceptance (acquiring) services to merchants. Table 2 shows the summary statistics for the banks that we have fee information on.[15]

Table 2: Acquirer side summary statistics

Acquirer Variables, $N = 599$	**mean**	**sd**	**max**	**min**	**median**
POS_location_BAX	348.09	781.04	6,402	1	18
bax_trans (millions)	3.13	7.87	71.13	0	0.08
bax_value (billion NOK)	1.26	3.17	24.29	0	0.03
POS_reg_fee (NOK)	516.86	23.66	550	500	500
POS_settl_fee (NOK)	144.13	33.44	240	60	150
POS_trans_fee (NOK)	0.11	0.20	2	0	0.15
interest_loan_corp (%)	5.79	1.31	9	3.83	5.65
interest_deposit_corp (%)	3.31	1.31	5.44	1.44	2.55

There are three fees that merchants pay for BAX card acceptance services: a one-time fee to register a POS terminal (*POS_reg_fee*), a monthly settlement fee (*POS_settl_fee*), and a BAX card transaction fee (*POS_trans_fee*). The first fee, the POS registration fee, is a one-time fee that merchants pay to set up a POS terminal and, as the table shows, does not vary much across the banks; the minimum is 500 NOK and the maximum is 550 NOK with the standard deviation less than 25. The second fee, the settlement fee, is a fixed fee that merchants pay every month and varies most among the three fees with the minimum 60 NOK and the maximum 240 NOK. The third fee, the transaction fee, is a fee that merchants pay every time their customers use their BAX cards. Merchants pay the fee set by their banks (the acquirer) regardless of which bank their customers are associated with. Some banks do not charge this fee; three banks did not charge this fee for the whole sample period and two

[15]There are significant number of missing values for BAX transactions and fees on the merchant side. We explain in detail the assumptions and procedures we used to impute some of these in Appendix A.2.

banks did not charge it in at least one year during the sample period. For those who charge the transaction fee level went down over time. The average fee level among these banks was 0.41 in 2006 but went down to 0.17 in 2009.

The transaction fee for merchants is relatively low compared to the transaction fee that consumers pay to their banks. As shown in table 1 the average transaction fee for consumers is 2 NOK and the maximum is 4 NOK. As table 1 and table 2 show the interest rates for merchants are slightly higher than those for consumers. The average interest rates on deposit accounts is 3.24% for merchants while it is 3.2% for consumers, and the average interest rates on loans is 6.02% for merchants while it is 5.5% for consumers.

3.3 POS Survey Data

An additional dataset, drawn from a survey conducted by Norges Bank, adds micro-level information which we will use on the issuer and acquirer side. The survey contains detailed information on individuals' payment choices in Norway over a week in 2007 for a representative sample of 2608 respondents. For a total of 2191 transactions, the transaction amount, the type of purchase, which payment instruments were available for that transaction, the means of payment, the store type, and a range of information about the respondent are recorded. The survey finds that BAX cards are the mostly frequently used payment method at point of sales with 67% of POS transactions settled by BAX cards. The next main payment instrument at POS is cash accounting for 23% of POS transactions, whereas credit cards and petrol companies' cards together account for only 10% of POS transactions. See Table 3 in Gresvik and Haare (2008) for more detailed information on the choice of payment methods at POSs and in general for information on the survey data.

For the consumer side of the model, as described in further detail in Section 5.1 and Appendix B.2, we will make use of the ratio of debit card payments out of the total number of transactions to estimate the aggregate bank-specific total number of transactions across all payment methods. On the merchant side, transaction-level information on the type of store, combined with information about the distribution of retailer types in all markets obtained from Statistics Norway, will help in obtaining merchant-type specific numbers of card transactions. Using this information will hence enable us to consider merchant heterogeneity.

4 Reduced form evidence

4.1 Issuer side

We begin by running linear regressions for the BAX card usage and for the value on deposit accounts to estimate reduced-form demand models. In these regressions we focus on estimating the price elasticity of the BAX card usage with respect to the BAX transaction fee and the price elasticity of the deposit value with respect to the BAX annual fee and the effective BAX fee, which is the sum of the BAX annual fee and the BAX transaction fee multiplied by the total number of BAX transactions.

Table 3 shows estimation results of the semi-log regressions for the BAX usage. We use the number of BAX transactions divided by the value of deposit accounts as the BAX usage variable ($ln(usage/deposits)$) to control for high (low) BAX transactions resulting from large (small) market shares at the bank choice. The BAX transaction fee is the price variable in the regressions. In the second and fourth regression columns we add the deposit interest rate as an explanatory variable. The idea behind including the deposit interest rate in card usage regressions is that it is a measure of the cost of holding cash (in pocket) and so might affect the payment method choice between debit card and cash. We treat BAX transaction fee and deposit interest rate (when included) as endogenous variables and run both OLS and GMM with the optimal weighting matrix. In all regressions we include the year fixed effects, the bank fixed effects and the county fixed effects.

We use the number of competitors' branches as BLP instrument (Berry et al. (1995)). We also use wages per employees, transmission cost per BAX card transactions, and loan interest rates as instruments for BAX transaction fee and deposit interest rate. The unit cost variables (wage/employee and transmission cost/BAX transactions) should not be correlated with unobserved components for BAX usage. The loan interest rate is an interest rate that banks apply to customers' loans so customers should care about this when they make bank choices but not when they decide whether to use their BAX cards or not.

Table 3 shows that the BAX transaction fee has a negative, but close to zero, and statistically significant coefficient in the OLS regressions. Deposit interest rate has a negative, but statistically insignificant effect on BAX usage per deposit value. The magnitude of price coefficient implies that the BAX usage holding the deposit value goes down by 0.06% when the BAX transaction fee goes up by 1 NOK (the first column). The price coefficient, however, becomes much more negative and statically significant (at a 0.05 significance level), and deposit interest rate has a negative and statistically significant effect in the GMM estimation. The implied semi-price elasticity is about 0.52, implying that the BAX usage holding the deposit value would go down by 0.52% when the transaction fee goes up by 1

NOK (the last column). The coefficient of deposit interest rate implies that the BAX usage holding the deposit value would go down by 0.98% when the deposit interest rate goes up by 1 %. This negative reaction of BAX usage to deposit interest rate is surprising given that we expect costs of holding cash in pocket to increase in deposit interest rate and so a higher deposit interest rate making it more attractive to use debit card instead of cash. The negative reaction of BAX usage holding the deposit values could be explained by the fact that consumers care deposit interest rates more when making an issuer bank choice than choosing between card and cash at POSs. If there is a strong positive effect of deposit interest rates on the issuer market shares, which are measured by value on deposits, this could be the deriving force behind the negative coefficient of deposit interest rates on card usage holding the deposit values. Indeed, we document below the strong effect of deposit interest rates on the banks' market shares in terms of the deposit value.

The branch variable has negative and statically significant coefficients in all regressions, implying that the BAX usage per the deposit value is lower in a county with more branches. However, the magnitude is small and implies that the BAX usage is only about 0.04% lower in a county with one more branch. This suggests that the number of branches has negligible impact on the BAX usage. As will be shown below, the branch variable has much bigger and positive impact on the deposit value or the banks' market shares in terms of the deposit value.

Table 3: Linear regressions for BAX Usage

$N = 1824$	$\ln(usage/deposits)$			
	OLS	OLS	GMM	GMM
Transaction fee	-0.06***	-0.05*	-0.57**	-0.52**
	(0.020)	(0.028)	(0.227)	(0.250)
# Branches	-0.04***	-0.04***	-0.04***	-0.04***
	(0.009)	(0.009)	(0.003)	(0.003)
Deposit interest		-0.10		-0.98*
		(0.194)		(0.526)
Constant	8.74***	8.92***	9.77***	11.61***
	(0.102)	(0.329)	(0.478)	(1.205)
R^2	0.45	0.45		

Notes: Robust standard errors (for OLS, clustered at the bank level) in parentheses. Two-step efficient GMM estimates with transaction fee and deposit interest as endogenous regressors. Bank, county, year fixed effects are included in all regressions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We next turn to the relationship between the value on deposit accounts and fees that banks charge to their customers for various retail banking services. These fees include BAX card fees as well as fees for other banking services that are widely used by consumers and might therefore matter for their bank choices, namely ATM withdrawals, direct debits, internet banking solutions, and loans, see Norges Bank (2009). We run the semi-log regressions for the deposit value with three different price variables. The first price variable is the "BAX fee", which is the sum of the annual BAX fee and BAX transaction fee. The second is the "other fee", which is the sum of the fees corresponding to other important services that banks offer: the loan interest rate, the ATM fee, the direct debit (avtalegiro) fee, and the net (internet banking) fee. For the ATM fee we sum the ATM fee that the banks charge to their own customers and the ATM fee that they charge to other banks' customers. There is another important retail banking service widely used by consumers, which is online bill payments (e-invoice). We do not include e-invoice fee since it is very highly correlated with internet banking fee (with correlation of 0.92). In Appendix B.3.1, Table 9, we document pairwise correlations between fees of retail banking services that we consider for consumers' bank choice. The third is the "effective BAX fee", which is the sum of annual BAX fee and BAX transaction fee multiplied by the total number of BAX transactions of a given bank. By using the effective BAX fee we aim to see how banks' value on deposit accounts are affected by total costs of holding and using BAX cards proportional to their usage amount.

Table 4 reports estimation results from three sets of the semi-log regression. In each set we run two regressions, an OLS regression and the GMM with instruments for the price variables, and in all regressions we include the branch variable, the year fixed effects, the county fixed effects, and the bank fixed effects. We construct the instruments using the wage and the transmission fee. We use the transmission fee as it is but interact the wage variable with the county dummy variables and select four (out of 19) that are highly correlated with the price variables. The first stage F-statistics on the joint significance of these instruments is 9.91 for the BAX fee, 26.77 for the sum of other fees, and 79.09 for the effective BAX fee.

In the first set of the regressions where we use the BAX fee as the price variable the BAX fee's coefficient is negative, but statistically insignificant in the OLS (column 1). It becomes more negative and significant at a 0.20 significance level in the GMM (column 2). The GMM estimate implies that the value of deposit accounts goes down by 0.021% when the BAX fee goes up by 1 NOK. In the second set of the regressions, where we add the sum of other fees in the OLS, the coefficients of the BAX fee and the other fees are statistically insignificant (column 3). The GMM estimate of the other fees (dropping BAX fee) is also insignificant and positive (column 4). In the third set of regressions, where we have the effective BAX fee as the only price variable, the OLS estimate of the coefficient of the effective price is negative and significant at a 0.05 significance level (column 5). It becomes even more significant and

Table 4: Linear regressions for value on deposits

$N = 1824$	(1) OLS	(2) GMM	(3) OLS	(4) GMM	(5) OLS	(6) GMM
BAX fee	-0.001	-0.021*	-0.000			
	(0.001)	(0.013)	(0.001)			
Other fees			0.029	0.058		
			(0.025)	(0.143)		
Effective BAX fee					-0.073***	-0.183***
					(0.010)	(0.026)
# Branches	0.193***	0.190***	0.193***	0.198***	0.279***	0.399***
	(0.031)	(0.013)	(0.031)	(0.012)	(0.030)	(0.032)
Constant	0.548	5.553*	0.032	-0.536	0.437	0.469
	(0.434)	(3.119)	(0.587)	(2.346)	(0.296)	(0.323)
R^2	0.79		0.79		0.81	

Notes: In all regressions bank, county, year fixed effects are included. Standard errors in parentheses. * $p < 0.20$, ** $p < 0.10$, *** $p < 0.05$.

more negative with the semi-price elasticity around 0.2 in the GMM (column 6). The branch variable is about 0.20 and statistically significant at a 0.05 significance level in first two sets of regressions, and it becomes more significant and larger (0.4) in the GMM estimation with the effective BAX fee.

These results suggest that the BAX fees matter in customers' bank choices and they matter even more if we account for the total BAX fees proportional to BAX usage, that is, using the effective BAX fee as the price variable. The semi-price elasticity is small but its economic impact is not negligible. The mean deposit value is about 1 billion NOK so a 0.2 semi-price elasticity implies that the banks would lose 2 million NOK in the deposit value by raising a fee by 1 NOK.[16] On the other hand, we have not found any significant effect of the sum of other fees on banks' deposit values. Finally, the number of branches is also an important factor for consumers' bank choices. Having one more branch office increases the bank's value on deposits by 0.4%, that is, around 4 million NOK.

4.2 Acquirer side

We next run semi-log regressions for the merchants' bank choice decisions. Table 5 shows merchant side reduced form regressions. In each regression, the left hand-side variable is the log of acquirer banks' market share over BAX point-of-sales (POSs). Due to lack of variation in POS registration fees and their relatively low value compared to annual settlement fees

[16] 1 NOK is about 15 cents in US dollars.

(518 NOK once vs 1714 NOK per year) (see Table 2), we consider settlement fees as the main fixed fees that merchants pay for card acceptance. Thus, we assume that the prices that matter for merchants when choosing an acquirer bank are settlement fees and POS transaction fees. In the first and third regression columns, the price variable is "merchant fee", which is the sum of the settlement fee and the POS transaction fee. In the second and fourth regression columns, the price variable is the "effective merchant fee", which is the sum of the settlement fee and the POS transaction fee multiplied by the volume of POS transactions of a given acquirer. As in the issuer side reduced form regressions, the effective fee variable here aims to capture the impact of the total costs accepting cards, fixed and transaction merchant fees proportional to the POS transactions volume, on the number of POSs acquired by banks. We treat the price variables as endogenous and run both OLS and GMM with the optimal weighting matrix. As above, in all regressions we include branch variable, the year fixed effects, the bank fixed effects and the county fixed effects.

Table 5: Linear regressions for merchant side market shares

$N = 599$	ln(Banks' point-of-sale shares)			
	OLS	OLS	GMM	GMM
Merchant fee	0.001		0.001	
	(0.001)		(0.005)	
Effective merchant fee		-0.619**		-0.756**
		(0.223)		(0.354)
# Branches	0.152***	0.212***	0.16***	0.224***
	(0.041)	(0.049)	(0.015)	(0.038)
Constant	-6.950***	-6.357***	-7.18**	-6.384***
	(0.646)	(0.433)	(3.351)	(0.652)
R^2	0.811	0.833		

Notes: Robust standard errors (for OLS, clustered at the bank level) in parentheses. Two-step efficient GMM estimates with the sum of merchant fees as an endogenous regressor. Bank, county, year fixed effects are included in each regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Similar to the issuer side, we use the number of competitors' branches as "Berry et al. (1995) instrument". We also use wages per employees, consumer side deposit and loan interest rates as instruments for the effective merchant fee. The wage/employee variable, consumer side deposit and loan interest rates should not be correlated with unobserved components of merchants' bank choice demand.

As Table 5 shows, the coefficient of the merchant fee is not significant and has the wrong sign (positive) in the OLS or GMM regressions (columns 1 and 3). However, the coefficient of “effective merchant fee” is significant and has the right sign (negative) in both OLS and GMM regressions (columns 2 and 4). Moreover, the magnitude of the effective fee coefficient increases and it becomes more signicant (at a significance level of 0.01) when we control for the endogeneity of the effective merchant fee (comparing columns 2 and 4). The effective fee coefficient implies that when a bank increases its effective merchant fee by 1 NOK, its market share over POSs declines by 0.8%. Branch variable's coefficient is significant and positive in all regressions. It has the highest magnitude and lowest standard error in the GMM regression with the effective merchant fee (column 4). This coefficient implies that one more branch an acquirer bank has in a given market, its merchant side market share increases by 0.224 %.

5 Model

5.1 Consumer (issuer) side: card usage and bank choice

Our modeling approach incorporates two-stage decision making on the consumer side: consumers' bank choices followed by payment card usage choices at point-of-sales. This enables us to separately identify the extensive margin, that is, how consumers' bank choices react to changes in card fees and bank characteristics, and the intensive margin, that is, how consumers' card usage choices react to changes in card transaction fees. Importantly, we do payment card usage estimation conditional on bank choice to account for the fact that consumers self-select to banks in their bank choice. For instance, less price sensitive consumers choose a more expensive bank and we control for this in estimating their card usage demand.[17]

Usage choice We model consumers' payment method choice at physical point-of-sales (POS). Consider consumer i who holds a debit card issued by bank j. For a given transaction this consumer decides whether to use debit card j or other means of payment she holds. The main alternative payment method is cash as discussed in Section 3.3. The payment method decision is conditional on holding bank j's debit card because consumers do not change their banks on a daily basis. Let this consumer's utility of using the debit card of bank j for transaction r in market t be defined as

$$\upsilon_{ijtr} = \delta_{jt} - \alpha_i f_{jt} + \epsilon_{ijtr},$$

[17]If we did not account for consumer self-selection at the bank choice, we would have explained high card usage at high card usage fees by high benefits of using a card, however this usage behavior instead might result from less price sensitive consumers' demand.

where δ_{jt} denotes the benefit of using the card that depends on bank and market characteristics, $\delta_{jt} = \mathbf{x}_{jt}\beta + \xi_{jt}$, where $\mathbf{x}_{jt}$ is a vector of observable characteristics and ξ_{jt} is an unobservable characteristic (observed by consumers and banks but not by the econometrician). A consumer at bank j pays fee f_{jt} per transaction, α_i is her marginal disutility of paying the fee, and ϵ_{ijtr} is an idiosyncratic benefit that is distributed $i.i.d$ across consumers, markets, banks, and transactions with a cumulative distribution function $G(\theta_1)$. Coefficient α_i represents consumer heterogeneity with respect to price sensitivity and is assumed to be distributed with a cumulative distribution function $H(\theta_2)$.

We normalize the other means of payment to be an outside option that generates value υ_{i0tr} to the consumer and set the non-idiosyncratic part of the utility of this outside option to zero such that

$$\upsilon_{i0tr} = \epsilon_{i0tr}.$$

Consumer i (who holds a debit card issued by bank j) in market t uses bank j's debit card for transaction r if and only if the utility of using the card exceeds that of using an alternative payment method. Like in commonly used discrete choice models, we assume that $G(\theta_1)$ is the Type I Extreme Value distribution and so the conditional probability that consumer i uses the debit card of bank j for transaction r is

$$\Pr(\upsilon_{ijtr} \geq \upsilon_{i0tr} | i \in \mathbb{N}_j) = \frac{exp(\delta_{jt} - \alpha_i f_{jt})}{1 + exp(\delta_{jt} - \alpha_i f_{jt})}$$

where $\mathbb{N}_j$ denotes the set of customers of bank j, and $i \in \mathbb{N}_j$ denotes consumer i is a customer of bank j.

The "market size" for card usage is defined as the total number of all payment transactions at point-of-sales (including non-card transactions) by this consumer, which we denote by R_{ijt}. The card usage demand by this consumer, D_{ijt}, is a portion of debit card transactions in all of her transactions and corresponds to

$$D_{ijt} = \Pr(\upsilon_{ijtr} \geq \upsilon_{i0tr} | i \in \mathbb{N}_j) R_{ijt} = \frac{exp(\delta_{jt} - \alpha_i f_{jt})}{1 + exp(\delta_{jt} - \alpha_i f_{jt})} R_{ijt}. \tag{1}$$

We do not have data on the individual-level total number of transactions, R_{ijt}, so we assume that

Assumption 1 *Each consumer of bank j in a given market t makes the same number of total payment transactions.*

This assumption implies that $R_{ijt} = \frac{R_{jt}}{N_{jt}}$ for each $i \in \mathbb{N}_{jt}$ where R_{jt} denotes the total number of all transactions made by customers of bank j in market t and N_{jt} denotes the number of bank j's customers in market t.

To capture the fact that each consumer makes a bank choice and then card usage decision, and these decisions must be correlated due to the fact that they are made by the same person, we assume that

Assumption 2 *Consumer i's marginal disutility with respect to the card usage fee is the same as her marginal disutility with respect to the annual card fee.*

This assumption implies that consumer i's price coefficient at the card usage decision, α_i, is the same as her price coefficient at the bank choice. It is important to note that this assumption does not necessarily imply that consumers' price elasticity is the same for the card usage decision as the bank choice.

We obtain the bank-level card usage share by taking the expectation of the conditional probability of consumer i using bank j's debit card and then obtain the bank-level card usage demand by multiplying this bank-level card usage share by the number of total transactions by bank j's customers. The bank-level card usage share is

$$s^u_{jt}(\delta_{jt}, \alpha_i|\theta_2) = \int \frac{exp\,(\delta_{jt} - \alpha_i f_{jt})}{1 + exp\,(\delta_{jt} - \alpha_i f_{jt})} dH(\alpha_i|\theta_2, i \in \mathbb{N}_j), \tag{2}$$

where $H\,(\alpha_i|\theta_2, i \in \mathbb{N}_j)$ is the distribution of α_i conditional on α_i choosing bank j, and the bank-level card usage demand is $D_{jt} = s^u_{jt} R_{jt}$.

We need to use the conditional distribution rather than an unconditional distribution because price sensitive consumers likely select a bank with a lower annual fee (Assumption 2). Without accounting for this selection, the estimate of the card usage benefit, b_{ijt}, would be biased. As an example, suppose that we observe a high volume of card usage by customers at a high annual fee bank. If we ignore that these customers are less sensitive to prices than the average consumer, we may overestimate the card usage benefit. By accounting for the correlation in the marginal disutility of price, we would not attribute this high card usage volume to high card usage benefits more than we should. We illustrate this in more detail in Appendix B.

The EV1 distributional assumption in the card usage model allows us to compute consumer i's expected benefit of using bank j's debit card, given her marginal disutility of money, α_i, as

$$b_{ijt} = log\,(1 + exp\,(\delta_{jt} - \alpha_i f_{jt})) \tag{3}$$

Bank choice Consumers make a bank choice based on, among other things, the expected net benefit of card usage and how many transactions they expect to have. Thus b_{ijt} should be part of the utility of bank membership. For a bank charging F_{jt} as the annual card fee, which does not vary with the amount of transactions, the effective price that a consumer faces is

$$p_{ijt} \equiv F_{jt} - \frac{b_{ijt}}{\alpha_i} E\left(D_{ijt}\right) \tag{4}$$

where $E\left(D_{ijt}\right)$ is the number of debit card transactions she expects to make in a period.

Consumer i's net utility from choosing bank j is defined as

$$u_{ijt} = \Delta_{jt} - \alpha_i p_{ijt} + \varepsilon_{ijt}$$

for consumer $i = 1, ...I_t$, bank $j = 0, 1, ..., J$, and market $t = 1, ..., T$, where we define mean utility $\Delta_{jt} = \mathbf{x}_{jt}\gamma + \zeta_{jt}$. Mean utility is composed of a K-dimensional row vector of observable bank characteristics $\mathbf{x}_{jt}$, the utility derived from unobserved bank characteristic ζ_{jt}, and ε_{ijt}, a mean-zero idiosyncratic error term. Replacing p_{ijt} with equation (4), we rewrite the utility as

$$u_{ijt} = \Delta_{jt} + b_{ijt} E\left(D_{ijt}\right) - \alpha_i F_{jt} + \varepsilon_{ijt}$$

We treat having a deposit account at banks not included in our sample as an outside option and normalize its mean utility to be 0 such that[18]

$$u_{i0t} = \varepsilon_{i0t}.$$

Assuming that ε_{ijt} and ε_{i0t} are i.i.d. across individuals, banks and markets with Type I Extreme Value distribution, we obtain bank j's market share for customers in market t as

$$s_{jt} = \int \frac{exp\left(\Delta_{jt} + b_{ijt} E\left(D_{ijt}\right) - \alpha_i F_{jt}\right)}{\sum_{j=0}^{J} exp\left(\Delta_{jt} + b_{ijt} E\left(D_{ijt}\right) - \alpha_i F_{jt}\right)} dH(\alpha_i|\theta_2). \tag{5}$$

5.1.1 Importance of other banking services for consumers' bank choice

Note that banks offer many other services to consumers, amongst which internet banking solutions, direct debit payments, electronic bill payment (e-invoice), and ATM withdrawals are the most frequently used ones. Given that consumers use these other services frequently, they should care also about the fees of these services. Our bank choice model does not account for these services' fees and usage amounts due to lack of good quality data on usage volumes

[18] All consumers above the age of 18 are eligible to have a deposit account and almost all eligible consumers have a deposit account in Norway. Hence, our market definition does not include the portion of eligible consumers that do not have a deposit account.

of these services and difficulty of finding instrumental variables for many endogenous fees. We would have biased estimates of consumers' bank demand elasticities if these other services were significant for consumers' bank choice decisions. Using complementary national- and bank-level data on usage volumes and fees of these other services, we assess whether these services could be important drivers of consumers' bank choices. To do that we calculate what percentage of the total costs of consumers' retail banking services correspond to these other services and what percentage corresponds to BAX card fees for an average customer of a given bank in a given year from 2006 to 2008. See Appendix B.3 for details of these calculations. We find that for 22 banks out of 24, BAX card fees correspond to above 80% of retail banking costs of their consumers. For the other two banks BAX card fees' share over the total consumer costs are 73% and 79%. These calculations illustrate that a major part of consumers' retail banking costs is due to BAX card fees (annual and usage fees), and consumers' bank choice should therefore mainly depend on BAX card services and their fees. Hence, our bank choice model captures the main driver of consumers' bank choice.

Even though consumers' bank choices do not depend on the other services' fees, banks might use debit cards (or deposit accounts) to cross sell consumers other services. In that case, our counter factual exercises would not capture how banks would react in setting fees of the other services when they face a shock on BAX card services' costs. We argue that banks do not use cross-selling: If cross-selling was present, we would have negative correlation between card fees and other service fees: Banks lower card fees to attract consumers and make profits by raising their usage fees of other services. Indeed, we find that banks' fees of the other important banking services (internet banking, direct debit, electronic bill payment, ATM withdrawal) have high positive correlation with their card transaction fee and very low negative correlation with card fixed fees.[19]

5.2 Merchant (acquirer) side: bank choice

Nearly 99% of merchants in Norway accept BAX card payments, so we assume that all merchants accept BAX card payments without modeling their card acceptance decisions and focus on merchants' bank choice decisions. In our model merchants use their banks to procure payment card acceptance (acquiring) services. Merchants' bank choice depends on the acquirers' merchant fees and other bank characteristics. The total fee each merchant pays is determined by the number of BAX card transactions to be settled in its store.

[19]For instance, the correlation between card usage fee and direct debit fee is 0.8, the correlation between card usage fee and e-invoice fee is 0.7, and the correlation between the card usage fee and ATM withdrawal fee (from another bank's ATM) is 0.64. See Appendix B.3.1 for the full table of pair-wise correlations between banks' prices of different retail banking services for consumers.

Thus, merchants' expectation about the number of BAX card transactions affects their bank choices.

Merchants that accept BAX card payments cannot influence consumers' choice of payment methods at the point of sales, and so the only decision merchants make is which bank to use as an acquirer.[20] In such a situation only the average merchant fee matters for merchants' bank choice decisions and when merchants are homogenous only one fee is sufficient to price merchants (capture their entire surplus), i.e., two-part tariffs (a lump-sum fee and a transaction fee) are redundant pricing tools for bank; the fixed merchant fee and transaction merchant fee cannot be identified separately in the optimal pricing conditions of banks. We show this in Appendix C.1. To understand the intuition suppose that an acquirer bank lowers its per-transaction fee and increases its fixed merchant fee by an amount such that it keeps its average merchant fee constant at a given amount of card transactions in that market. Merchants accepting BAX cards cannot influence the total card transactions at their store, so the reduced per-transaction merchant fee will not affect the total number of card transactions at a given merchant. What matters for each merchant is the average merchant fee paid to the acquirer, which will be the same as before (by construction), and thus this fee change will not affect the merchants' bank choice (see Bedre-Defolie and Calvano (2013) for more details).

To rationalize widely used two-part tariff merchant fees and capture the fact that merchants are indeed heterogenous, we assume that merchants differ in the average number of BAX card transactions they process. For instance, large grocery stores and small convenience stores should differ in their amount of card transactions in a given market. We assume that there are 2 types of merchants in each market: a type A merchant processes more transactions than a type B merchant (in Section 6.2.1 we explain precisely how we define merchant types). Allowing for merchant heterogeneity along this dimension enables us to rationalize two-part tariff merchant fees: banks price discriminate across different merchant types such that a merchant who processes a higher transaction volume pays its acquirer bank a lower average tariff. We show this identification in the next section when we solve a bank's optimal pricing problem. To understand the intuition suppose again that an acquirer bank lowers its per-transaction fee and increases its fixed merchant fee by an amount such that it keeps its average merchant fee constant for the marginal merchant who processes $\overline{w}$ amount of card transactions in that market. The marginal merchant is the one whose convenience benefit

[20] Up to 2009 in Norway merchants were not allowed to price discriminate based on consumers' payment choice. Since the change of regulation in 2009, merchants can surcharge expensive payment methods or discount cheap payment methods. Even after the regulation, very few merchants started to price discriminate based on the choice of payment method, see Norges Bank (2012). Our sample is from 2006 to 2009, we therefore assume that merchants are not allowed to price discriminate between different payment methods.

from processing $\overline{w}$ transactions, $\overline{b_S}$, is equal to its average fee: $\overline{b_S} = m + \frac{M}{\overline{w}}$.[21] Merchant types that process less than $\overline{w}$ would have a higher average merchant fee than before if they choose that acquirer and so some of these infra-marginal merchants will switch from that acquirer to the rival acquirers. On the other hand, merchant types that process more than $\overline{w}$ amount of card transactions would have a lower average merchant fee than before, and so some of these merchants who were customers of the rival acquirers before will switch to that acquirer. In other words this fee change will affect merchants' bank choices in general (except for the marginal merchant type) and the acquirer sets its per-transaction merchant fee at the level where the gains from attracting high-transaction merchants from the rivals is equal to the losses from losing low-transaction merchants at the given level of average merchant fee for the marginal merchant.

Let N_{kt}^S denote the number of k-type merchants for $k \in \{A, B\}$, and N_t^S denote the total number of merchants in market t such that

$$N_{At}^S + N_{Bt}^S = N_t^S.$$

We assume that the total number of merchant types constant, so do not vary with merchant fees or the total card transaction volume in a given market: N_{kt}^S is constant for $k \in \{A, B\}$ for every market t.

Let D_{kt}^S be the total number of BAX card transactions made at merchant type k. Then, the average number of BAX card transactions made at a k-type merchant in market t is

$$w_{kt} = \frac{D_{kt}^S}{N_{kt}^S}$$

We define the utility of merchant type k who chooses bank j in market t as

$$\pi_{kjt} = x_{jt}\lambda - \mu(M_{jt} + m_{jt}E(w_{kt})) + \zeta_{jt} + \upsilon_{ijt}, \tag{6}$$

where x_{jt} captures the acquirer bank's characteristics, M_{jt} is the monthly merchant fee, m_{jt} is the per-transaction merchant fee, ζ_{jt} refers to the other characteristics of acquirers that are observed by merchants and acquirers, but not by econometricians, and υ_{ijt} denotes random taste shocks on the merchant's utility. Note that the impact of the per-transaction merchant fee on the merchant's utility is proportional to the amount of card transactions the merchant expects to handle in that market, w_{kt}.

[21] We assume merchants are heterogenous in two dimensions, (b_S,w), and the marginal types are the ones on the curve $b_S = m + \frac{M}{w}$. In other words, for given (m,M) there are infinitely many marginal types (that are on the curve) if we consider the full-support of w. So for a given b_S there is one w that satisfies the relationship, $b_S = m + \frac{M}{w}$.

One important aspect of this model is that w_{kt} will be the term through which the consumer (issuer) side affects the merchant (acquirer) side. Suppose the card usage (transaction) fee that consumers pay goes down in market t. This fee change on the issuer side would increase the total payment that merchants make to their acquirer banks through a higher amount of card transactions by consumers. As a result, even if acquirer banks do not change merchant fees, each merchant's average merchant fee from a given acquirer changes since each merchant's expected amount of card transactions, w_{kt}, increases due to the consumer fee reduction. Probably, high volume merchants expect to process more of the increased card transactions, so their average merchant fee from a given acquirer decreases more than low volume merchants. More specifically, w_{At} increases more than w_{Bt} when total card transactions, D_t, increase.

We treat having a BAX card acquiring services agreement with banks that are not in our sample as an outside option, which generates the value of π_{k0t} to merchant type k. We set the non-idiosyncratic part of the utility of this outside option to zero such that

$$\pi_{k0t} = \upsilon_{k0t}.$$

Assuming that υ_{kjt} and υ_{k0t} are i.i.d Type I Extreme Value across merchants, banks and markets, we obtain bank j's market share for merchant type k in market t as

$$s^S_{kjt} = \frac{exp\left(x_{jt}\lambda + \zeta_{jt} - \mu(M_{jt} + m_{jt}w_{kt})\right)}{\sum_{j=0}^{J} exp\left(x_{jt}\lambda + \zeta_{jt} - \mu(M_{jt} + m_{jt}w_{kt}\right)}, \tag{7}$$

5.3 Bank Problem

In every period banks earn the issuer profits from card transactions made by their cardholders and the acquirer profits from card transactions settled at their merchant locations. Until now a market is defined by a county-year combination, but here we abuse the notation and denote county by c, and time by t. The reason of the notation change is to take into account the fact that each bank sets the same fees in all counties in a given year (national pricing policy). We drop the subscript for time, t, to simplify the notation.

On the issuing side let C^I_j denote bank j's cost of providing issuing services to a cardholder and c^I_j denote bank j's cost of issuing one card transaction. On the acquiring side, C^A_j denotes bank j's cost of providing acquiring services to a merchant and c^A_j denotes bank j's cost of acquiring one card transaction. This notation reflects the fact that the cost of an electronic transaction is the same regardless of which county it is processed in (both for the issuer and the acquirer), but the issuing and acquiring costs still vary across banks and across years. We assume that the cost of issuing one card or acquiring a merchant does not depend on the location of the end user (cardholder/merchant). Bank j's profit is then

$$\Pi_j = \Pi_j^I + \Pi_j^A = \sum_c [(f_j - c_j^I)D_{jc} + (F_j - C_j^I)N_{jc}^B + (m_j - c_j^A)\sum_k w_{kc}N_{kjc}^S + (M_j - C_j^A)\sum_k N_{kjc}^S].$$

The first term corresponds to the variable issuer profits from card transactions settled by bank j's cardholders: the variable issuer margin, $f_j - c_j^I$, times the total card usage demand of its cardholders in all counties, $\sum_c D_{jc}$, where D_{jc} is card usage demand of bank j's customers in county c. The second term is the fixed (with respect to transactions) margin times the total number of the bank's cardholders, $\sum_c N_{jc}^B$, where N_{jc}^B is the number of the bank's cardholders in county c. The third term is the variable acquirer profits from card transactions settled at the merchant locations that are the customers of the bank: the variable acquirer margin, $m_j - c_j^A$, times the expected card usage demand in county c at all merchant locations acquired by the bank, $\sum_c \sum_k w_{kc}N_{kjc}^S$, where N_{kjc}^S is the total number of k-type merchants acquired by bank j in county c, and w_{kc} is the average number of BAX card transactions processed by a k-type merchant in county c. Finally, the fourth term is the fixed acquirer margin from the bank's merchants. Bank j maximizes its profit with respect to four different prices, f_j, F_j, m_j and M_j. The optimal prices of bank j are determined by the following first-order conditions:

$$FOC_{f_j} : \sum_c \sum_k [D_{jc} + (f_j - c_j^I)\frac{dD_{jc}}{df_j} + (F_j - C_j^I)\frac{dN_{jc}^B}{df_j} + (m_j - c_j^A)\left(N_{kjc}^S \frac{dw_{kc}}{df_j} + w_{kc}\frac{dN_{kjc}^S}{df_j}\right) + (M_j - C_j^A)\frac{dN_{kjc}^S}{df_j}] = 0$$

$$FOC_{F_j} : \sum_c [N_{jc}^B + (f_j - c_j^I)\frac{dD_{jc}}{dF_j} + (F_j - C_j^I)\frac{dN_{jc}^B}{dF_j}] = 0$$

$$FOC_{m_j} : \sum_c \sum_k [w_{kc}N_{kjc}^S + (m_j - c_j^A)w_{kc}\frac{dN_{kjc}^S}{dm_j} + (M_j - C_j^A)\frac{dN_{kjc}^S}{dm_j}] = 0$$

$$FOC_{M_j}: \sum_c \sum_k [N^S_{kjc} + (m_j - c^A_j) w_{kc} \frac{dN^S_{kjc}}{dM_j} + (M_j - C^A_j) \frac{dN^S_{kjc}}{dM_j}] = 0$$

Using equation (6) we can derive the equivalence between the reaction of merchant type k's demand in each county to the transaction fee and to the fixed fee:

$$\frac{dN^S_{kjc}}{dm_j} = w_{kc} \frac{dN^S_{kjc}}{dM_j}$$

Replacing this into the first-order condition for m_j we rewrite the latter as

$$FOC_{m_j}: \sum_c \sum_k w_{kc} [N^S_{kjc} + (m_j - c^A_j) w_{kc} \frac{dN^S_{kjc}}{dM_j} + (M_j - C^A_j) \frac{dN^S_{kjc}}{dM_j}] = 0$$

Since the latter condition is different from the first-order condition for M_j and both conditions can hold at the same time, the merchant fees are separately identified in this model (see Appendix C.2 for an illustration of identification for a bank which is active in only one county).

Note that the card usage volume at merchants of type k in county c, D_{kc}, affects these merchants' total card usage fee payments via changing $w_{kc} = \frac{D_{kc}}{N^S_{kc}}$ (see equation (6)). Hence, merchants' demand reactions to merchant fees in county c depend on the total volume of card transactions at merchant type k, D_{kc}, and the total number of k-type merchants, N^S_{kc}. Observe that D_{kc} should correspond to the total volume of card transactions made by all cardholders at k type merchant locations in county c: $D_{kc} = \sum_{j=0}^{J} D_{kjc}$. Moreover, the total number of k-type merchants is equal to the sum of the k-type merchants of all banks: $N^S_{kc} = \sum_{j=0}^{J} N^S_{kjc}$.

In order to solve each bank's first-order condition with respect to its card usage fee, FOC_{f_j}, we need to identify how the bank's card transaction fee will affect the average volume of card transactions at merchant type k, $\frac{dw_{kc}}{df_j}$, and how the card transaction fee will affect the merchant type specific market share of that bank as an acquirer: $\frac{dN^S_{kjc}}{df_j}$. In section 6.2.2, we show how to identify these merchant type specific derivatives using our data on the merchant side.

The derivative $\frac{dw_{kc}}{df_j}$ links the merchant side to the consumer side via the effect of card usage fees on the total volume of card transactions at a given merchant. To see the mechanism consider the example of two banks, 1,2, and two types of merchants, A, B, and one market. We can identify how merchants' bank choice changes when a bank, say 1, lowers its card usage fee to consumers: dN^S_{kj}/df_1 for all $j = 0, 1, 2$ and all $k \in \{A, B\}$. Due to the reduction in f_1 more consumers choose bank 1, N^B_1 increases, and less consumers choose the rival, N^B_2

decreases. Moreover, existing consumers of bank 1 will use their debit cards more. As a result, D_1 increases and D_2 decreases, but $D_1 + D_2 = D$ should increase (own-demand effect of f_1 dominates the cross-demand effect), say by ΔD. Hence, merchants' expected amount of card payments increases: $D_A = D_{A1} + D_{A2}$ increases, $D_B = D_{B1} + D_{B2}$ increases, given that $D = D_A + D_B$ and D increased by ΔD due to the reduction in f_1. This will affect how merchants are going to reshuffle between the banks (even if the banks do not change their merchant fees): both types of merchants will put more weight on transaction fees, m_1 and m_2, and the bank with a lower merchant transaction fee and a higher merchant fixed fee will attract more merchants than before the change in f_1. This reshuffling will probably occur at different levels for different types of merchants: we might expect small merchants to react more to a unit increase in the total amount of transactions than big merchants. On the other hand, the increased volume of transactions, ΔD, will not be equally allocated between large and small merchants: Large merchants should probably expect to receive more of the increased volume, $\Delta D_A > \Delta D_B$, if A refers to large merchants and B refers to small merchants. So even if small merchants might react more to a unit increase in the total volume of card transactions, after accounting for how the increased card transaction volume is distributed between the merchant types, large merchants' reaction in their bank choices might be larger than small merchants' reaction. More importantly, the variation in card transaction fees changes the average card transaction volume each merchant expects to obtain and thereby changes its average fee, $\frac{M_j}{w_k} + m_{jt}$, even if merchant fees, M_j, m_j, do not change. By using the moment conditions from the supply side equations, we exploit this link between the consumer side and merchant side to identify merchant side parameters more precisely by leveraging consumer side card fee variation.

6 Identification

6.1 Demand side parameters, aggregate data, and national pricing

As all banks offer deposit account and debit card products in all markets, we do not observe entry and exit. Hence, covariation in observable characteristics and market shares identifies our model parameters. While this frees us of the issue of choice set variation and consumer surplus estimation in logit models raised by Ackerberg and Rysman (2005), of relevance also for the planned counterfactual policy evaluations, our data alone are not sufficient to identify all model parameters in flexible ways. In interpreting our results, we need to keep in mind the tradeoffs we face in adding structure to help identify consumer and merchant price sensitivities.

In particular, as explained in the data section, a given bank's fees, both the fixed fee and the per-transaction fee, do not vary across counties. This national pricing means that the only price variation we observe for a given bank comes from price changes over time. However, the data shows that a number of the banks did not change their fixed fees during the sample period. Thus, we rely on consumers' response in the card usage with respect to changes in the per-transaction fee to identify the price sensitivity. Our assumption that the marginal disutility of a higher fixed fee is the same as the marginal disutility of a higher per-transaction fee (α_i in equation (2) is the same as α_i in equation (5) helps us estimate precisely consumers' elasticity to card transaction fee and the elasticity to fixed card fee.

6.2 Merchant side parameters

As we discussed in the previous section, allowing for merchant heterogeneity is necessary to rationalize two-part tariff merchant fees. However, our market level data does not provide information on the merchant type, that is, the amount of BAX transactions processed by individual merchants or merchant groups. We overcome this challenge by limiting the merchant types to two, A,B.

Hereafter, we drop the market identifier, t, to simplify equations, since each variable has the market identifier. Let N_{kj}^S denote the number of k-type merchants acquired by bank j and D_{kj}^S denote the number of BAX card transactions processed at a k-type merchant location of bank j, where $j \in \{0, 1, ..., J\}$ and $j = 0$ corresponds to the banks that are out of our sample. If N_{kj}^S are observed, the market share of bank j over type k merchants can be calculated by

$$s_{kj}^S = \frac{N_{kj}^S}{\sum_{j=0}^J N_{kj}^S}, \tag{8}$$

Then we match the calculated shares from (8) to the model predicted shares from (7) to estimate merchants' demand for acquirer banks.

6.2.1 Identifying merchant type specific market shares

We have data on how the total number of merchant locations and the BAX card transactions are allocated across acquirer banks, that is, we observe N_j^S and D_j^S for all j. However, we do not observe the merchant type-specific allocations of these market shares, that is, we do not observe N_{kj}^S or D_{kj}^S. We estimate them by solving the following system of equations. First, the total number of card transactions processed by the merchants of bank j in a given market, D_j^S, should be equal to the total amount of card transactions processed by all types of merchants that this bank acquires in that market:

$$w_A N_{Aj}^S + w_B N_{Bj}^S = D_j^S \tag{9}$$

Second, the total number of the different types of merchants that a bank acquires in a given market should be equal to the total number of merchants acquired by that bank:

$$N_{Aj}^S + N_{Bj}^S = N_j^S \tag{10}$$

Third, the total number of k-type merchants served by each acquirer in a given market should be equal to the total number of k-type merchants in that market.

$$\sum_{j=0}^{J} N_{kj}^S = N_k^S \tag{11}$$

We calculate w_k for $k \in \{A, B\}$ using the POS survey data on the merchant location of every BAX card transaction and the Statistics Norway data on the total number of merchant categories in a given market. From the POS survey data we observe the average number of BAX card transactions in each county processed at the categories of the merchant locations defined by the survey. We first group merchant locations observed in the POS survey data into two categories: type A, or "large volume," merchants for groceries and gas stations, and type B, or "small volume," merchants for the rest. We then calculate the ratio of BAX transactions that each merchant type processes in a given market using the Survey data. By multiplying this ratio with the total number of BAX card transactions observed in the bank-market-level data, we calculate the number of BAX card transactions that each merchant type processes in a given market, D_k^S. Lastly, we divide this by the number of each merchant type, N_k, observed in the Statistics Norway to calculate the average number of BAX card transactions that each merchant type processes, that is, w_A and w_B.

Given data on D_j^S, N_j^S, N_k^S, and w_k we solve the system of equations (9), (10), and (11) for unknowns $N_{kj}^S \ \forall \ j \in \{0, 1, .., J\}, k \in \{A, B\}$.[22]

[22]Note that we restrict the average number of BAX transactions for each merchant type to be the same regardless of the identity of the acquirer bank, that is, we do not allow w_k to vary across acquirer banks. Ideally, we would like to do that and define $w_{kj} = \frac{D_{kj}}{N_{kj}}$. However, due to the data limitations we would not able to identify merchant type and acquirer bank specific average volume parameters, w_{kj}. Assuming w_k to be the same across acquirer banks might lead to a bias if this is not the case in reality. For instance, consider an acquirer bank whose k-type merchant has the average volume of BAX transactions that is above the average of all k-type merchants: $w_{kj} > w_k$. If we assume in our model that $w_{kj} = w_k$, we will then devote the high volume of transactions processed by bank j's k-type merchants to the total number of $k - type$ merchants acquired by bank j, that is, overestimate N_{kj}^S. Symmetrically, for an acquirer bank whose k-type merchant has the average volume of BAX transactions that is below the average of all k-type merchants:

6.2.2 Identifying the derivatives of merchant type specific market shares with respect to a change in a consumer card fee

Let f_m denote the card transaction fee set by a given issuer bank m in our sample (so we fix m for the following identification exposition). To solve bank m's first-order conditions with respect to its card transaction fee we need to know how bank m's merchant-side shares of merchants and BAX transactions respond to a change in its card transaction fee: $\frac{dN^S_{km}}{df_m}$ and $N^S_{km}\frac{dw_k}{df_m}$. We can identify these derivatives using the available data for the two types of merchants, A and B, and previously recovered merchant type specific market shares, N^S_{kj}, and merchant type specific average volume of BAX card transactions, w_k.

First, let τ be a portion of the BAX transactions that type A merchants process in a given market. That is,

$$\tau = \frac{D^S_A}{D^S} = 1 - \frac{D^S_B}{D^S}$$

Assuming that τ is fixed for any level of D^S in a given market,

$$\frac{dD^S_A}{df_m} = \tau \frac{dD^S}{df_m} \tag{12}$$

The assumption that τ is fixed means that type A merchant always processes τ of total BAX transactions for any level of total BAX transactions in a given market, and equation (12) implies that for any change in total BAX transactions, τ of that change is always attributed to type A merchants.

Next, note that a change in the amount of BAX transactions on the issuer side from a change in bank m's card transaction fee is equal to total changes of BAX transactions on the merchant side. That is,

$$\sum_{j=0}^{J} \frac{dD_j}{df_m} = \sum_{j=0}^{J} \frac{dD^S_j}{df_m}. \tag{13}$$

When bank m lowers its card transaction fee, for example, the amount of BAX transactions on the issuer side will increase for two reasons. First, bank m's issuer-side customers will increase the amount of their BAX transactions at the point of sales. Second, some customers will switch from other banks to bank m and use the BAX card more frequently. This increased BAX transaction amount will be equal to the total changes of BAX transactions on the merchant side.

$w_{kj} < w_k$, we will underestimate N^S_{kj} if we assume that $w_{kj} = w_k$ in our model.

From equations (12) and (13) and the definition of w_A and w_B,

$$\frac{dw_A}{df_m} = \frac{1}{N_A^S}\frac{dD_A^S}{df_m} = \frac{\tau}{N_A^S}\sum_{j=0}^{J}\frac{dD_j}{df_m}$$

$$\frac{dw_B}{df_m} = \frac{1}{N_B^S}\frac{dD_B^S}{df_m} = \frac{1-\tau}{N_B^S}\sum_{j=0}^{J}\frac{dD_j}{df_m}$$

where $\sum_{j=0}^{J}\frac{dD_j}{df_m} = \sum_{j=0}^{J} R_{jt}\frac{ds_j^u}{df_m}$.

Once we obtain $\frac{dw_k}{df_m}$, we can calculate $\frac{dN_{kj}^S}{df_m}$ by differentiating the merchant side market share equation (7) with respect to f_m. That is,

$$\frac{dN_{kj}^S}{df_m} = N_k^S\frac{ds_{kj}^S}{df_m} = N_k^S\left\{-\mu s_{kj}^S\frac{dw_k}{df_m}\left[m_m\left(1-s_{kj}^S\right) - \sum_{l\neq j} m_l s_{kl}^S\right]\right\}. \tag{14}$$

where s_{kj}^S is the market share of bank j for merchant type k: $s_{kj}^S = \frac{N_{kj}^S}{N_k^S}$. In Appendix C.3 we provide an example of one market with 2 banks and an outside option, and illustrate how to identify merchant type specific bank shares and their derivatives with respect to a bank's card usage fee for consumers.

7 Estimation

We estimate a demand system that includes card usage, equation (2), and issuer bank choice, equation (5), using the generalized method of moments (GMM). Our estimation procedure is similar to that of BLP in that we equate the observed share to the model predicted share to recover the mean quality of products and then construct the moment condition under the assumption that the unobserved mean quality is orthogonal to exogenous variables.

One important difference, however, is that the card usage demand and the bank account demand are interdependent and we should account for this interdependence in estimating the demand system. The card usage demand depends on customers' bank choices because only those customers who chose bank j in a given year are relevant for the observed card usage for bank j's debit card in that year. Hence, the model predicted card usage in equation (2) accounts for each (simulated) consumer's bank choices by integrating individual usage choice probabilities over the cumulative distribution of consumer types conditional on bank choice, $dH(\alpha_i|\theta_2, i \in \mathbb{N}_j)$. In estimation, we weight each simulated consumer's usage probability by her likelihood of choosing bank j over the other consumers' likelihood of choosing bank j

(we illustrate this approximation by an example in Appendix B.1):

$$s^u_{jt}(\delta_{jt}, \alpha_i|\theta_2) \approx \sum_i \frac{exp\left(\delta_{jt} - \alpha_i f_{jt}\right)}{1 + exp\left(\delta_{jt} - \alpha_i f_{jt}\right)} \frac{s_{ijt}}{\sum_i s_{ijt}}$$

where

$$s_{ijt} = \frac{exp\left(\Delta_{jt} + b_{ijt} E\left(D_{ijt}\right) - \alpha_i F_{jt}\right)}{\sum_{j=0}^{J} exp\left(\Delta_{jt} + b_{ijt} E\left(D_{ijt}\right) - \alpha_i F_{jt}\right)}$$

and

$$b_{ijt} E\left(D_{ijt}\right) = log\left(1 + exp\left(\delta_{jt} - \alpha_i f_{jt}\right)\right) s^u_{ijt}(\delta_{jt}, \alpha_i|\theta_2) \frac{\hat{R}_{jt}}{N_{jt}}.$$

Bank choice also depends on card usage demand because the net benefit of using the debit card, b_{ijt}, is part of the effective price that consumers care. Thus, we need to calculate b_{ijt} for a given set of card usage demand parameters and plug this into the bank choice model. This interdependence between the card usage demand and the bank choice demand adds a computational burden in recovering the mean product qualities δ_{jt} and Δ_{jt}.

We do not observe the number of all transactions made by bank j's customers, R_{jt}, so we estimate $\hat{R}_{jt}$ under the assumption that it is the sum of debit card usage, D_{jt}, and a fraction of the money in the deposit account. We convert the value on deposit accounts by dividing it by the average debit card value of that bank's customers in that market. As we do not have data on what fraction of deposit value consumers use for POS purchases, we calculate this fraction by minimizing the distance between the likelihood of BAX usage calculated from the bank level data and the BAX usage likelihood estimated from the survey data. In Appendix B.2 we explain how we estimate $\hat{R}_{jt}$ in detail.

Besides the complication due to the demand interdependence our estimation procedure follows the standard GMM procedure used in the IO literature (Berry et al., 1995; Nevo, 2001). We first use the contraction mapping to estimate the mean quality of (1) the debit card usage and (2) the issuer bank. Then we construct the moment conditions that the unobserved quality of these two "products" are orthogonal to exogenous variables where the unobserved quality is the difference between the mean quality and the linear combination of product characteristics and the marginal utility of these product characteristics.

In the contraction mapping, we match the bank-specific model predicted card usage shares to the observed shares approximated as described above, that is:

$$s^u_{jt}(\delta_{jt}, \alpha_i|\theta_2) = \frac{D_{jt}}{\hat{R}_{jt}}.$$

To compute the contraction mapping for the bank choice shares, we calculate the observed market share of bank j in market t using our bank level data on the value of deposit accounts, where V_{jt} denotes the total value on deposit accounts held in bank j in market t:

$$s_{jt} = \frac{V_{jt}}{\sum_j V_{jt} + V_{0t}}, \tag{15}$$

where V_{0t} refers to the value of deposit accounts of the banks outside of our sample, on which we do have data. We then match the calculated shares from (15) to the theory predicted shares to estimate equation (5).

The estimation of acquirer bank choice by merchants type (equation (7)) is work in progress. Merchants are rather passive in our setup as they cannot choose the number of card transactions nor can they require surcharges for card transactions. Their only choice is the choice of bank given average card transaction fees. It is therefore difficult to identify merchants' card fee elasticities. We are currently working on combining moments generated from the supply-side optimal pricing conditions (FOCs) of banks and consumer-side demand estimation to estimate more precisely merchants' elasticities implied by the equilibrium model.

For instruments we use banks' unit cost variables such as wages per employee, rent per branch, and the transmission fee paid per debit card transaction[23]. In Appendix D.1, we show that the instruments constructed using the cost variables are not weakly correlated with either the per-transaction fee or the annual card fee. We also show in the log-linear regression setting, in Section 4, that while the OLS estimates of the price elasticity of the BAX usage and the deposit value are positive, the GMM estimates using these instruments are negative and statistically significant.

8 Estimation Results

We discuss a first set of results obtained from the estimation of the system of consumer side demand equations: card usage and bank choice. Table 6 reports the structural parameter estimates.

We assume that unobserved heterogeneity with respect to the price coefficient is distributed normal. In the consumer demand equations the parameters to be estimated are the mean, α, and standard deviation, σ, of the price coefficient, and the coefficient of branch. In the merchant demand equations the parameters to be estimated are the price coefficent, μ, and the coefficient of branch. On the consumer side, we add demographic information

[23]Transmission fees are paid by one bank to another for different types of payment transfers, including the ones for debit card payments, but not limited to debit card payments

Table 6: Sequential – consumer equations jointly, then merchant equations

	Consumer side		Merchant side	
	Usage	Bank		
Fee (α, μ)	-0.71*** (0.251)		-0.27*** (0.052)	
Fee (σ)	0.13 (0.313)			
Fee × income	0.48* (0.272)			
Branch	-0.02*** (0.003)	0.23*** (0.013)	0.53*** (0.083)	
Deposit interest	0.66*** (0.132)	0.48 (0.342)		
Corporate loan interest			-0.92 (2.084)	
Observations	1824	1824	1198	
$\eta_j(f_j)$ (mean)	-2.31	-0.95		
$\eta_j(F_j)$ (mean)	-5.81	-1.15		
b_{jt} (mean, in NOK)	0.51		Low	High
$\eta_j(m_j)$ (mean)			-0.13	-2.36
$\eta_j(M_j)$ (mean)			-1.69	-1.69

Notes: Random coefficient logit estimates. We first estimate card usage and bank choice demands of consumers jointly, and then estimate merchants' bank choice demands. All equations include bank, county, and year dummies. Market shares for random coefficient logit estimation are computed via simulation using modified latin hypercube sampling and draws from empirical income distributions (500 draws). 1 NOK = 11 Euro cents. Standard errors in parentheses: * $p < 0.10$, *** $p < 0.01$.

in estimation to reduce the reliance on distributional assumptions on the random coefficient by accounting for consumer heterogeneity observed at the aggregate level. In particular, we interact the price random coefficient with market-specific empirical income distributions. Table 6 suggests that income heterogeneity is an important factor in card usage and bank choice.

For both consumer side equations we use wage per employee, rent per branch, and transmission cost per BAX card transactions as instrumental variables (for card usage and holding fees). In addition to these direct cost-side instruments, we employ Berry et al. (1995)-type instruments, which are based on a competitive intensity argument. Specifically, we use the sum of competing banks' branches in each market. Intuitively, a higher (lower) overall number of competing branches should lead to lower (higher) profit margins as banks cannot differentiate by relying on their own branch network. Given marginal cost, lower (higher) profit margins imply lower (higher) prices. On the consumer side, first-stage F-statistics give us some confidence for our choice of instruments.

Our results on the consumer side show that holding a debit card generates significant benefits to consumers. In particular, we estimate the average convenience benefit of paying by debit card rather than any other method (conditional on bank choice) as 0.51 NOK (which is 5.4 Euro cents) per card transaction. We also find that at the bank choice consumers are elastic to changes in fixed fee, but inelastic to transaction card fee. The elasticity of issuer bank choice with respect to debit card fixed fee is -1.15 and to usage fee is -0.95. Moreover, debit card usage demand is elastic to card usage fee (with elasticity of -2.31) and to annual card fee (with elasticity of -5.81), where the latter elasticity should be mainly driven by bank choice elasticity. Including the income distribution as an observable measure of consumer heterogeneity and interacting it with the coefficient on transaction fees further shows that high-income consumers are less elastic to fees than low-income consumers (Fee x income variable has a positive and significant coefficient: 0.48). As expected branch network is a positive and very significant factor for consumers' bank choice. Deposit interest rate has also positive impact on bank choice, but it is statistically insignificant. Interestingly, branch network negatively affects card usage conditional on bank choice. This can be explained by the fact that the number of branches in a given market is highly correlated with the number of ATMs in a given market, and so a closer branch implies a lower cost of cash withdrawal and cash is the main alternative payment method to BAX debit cards in Norway. The deposit interest rate positively and significantly affects card usage conditional on bank choice. Intuitively, a higher interest rate on deposits means a higher cost of holding cash, and so makes card usage more attractive relative to cash.

As Table 6 shows branch network affects positively and significantly merchants' choice of an acquirer bank. Moreover, merchants' bank choice is significantly and negatively affected by merchant fees. As the economic theory predicts, high-volume merchants' acquirer demand is more elastic to transaction merchant fee than small-volume merchants' bank choice demand. Interestingly and unexpectedly, both merchant types' acquirer demand has the same elasticity to the fixed merchant fee.

To improve the precision of our merchant side demand estimates we use banks' first-order conditions for optimal consumer card fees and merchant fees. As explained in Section 6 our identification strategy is the following. The volume of card transactions at a given merchant type reacts to changes in card transaction fees in that market, since each merchant type expects to process more (respectively, less) card transactions when a card transaction fee decreases (respectively, increases) in its market. The extent of this reaction depends on whether the card transaction fee change affects a large portion of cardholders (that is, whether the issuer bank which changes the fee has a significant market share over consumers) in that market and on the type of merchants (large merchants expect to obtain a larger share of the changes in the total card transactions). More importantly, the variation in card transaction fees changes the average card transaction volume each merchant expects to obtain and thereby changes its average fee, even if individual merchant fees do not change. By using the moment conditions from the supply side equations, we exploit this link between the consumer side and merchant side to identify merchant side parameters more precisely by leveraging on consumer side card fee variation. The results of this analysis and the policy counterfactuals using demand and supply side estimates are in preparation.

Appendices

A Data

A.1 Issuer market: Missing values and their imputation

Table 7 provides a summary of the data on issuers: value on deposit accounts (value_deposit), total number of BAX card transactions (bax_trans), total value of BAX card transactions (bax_value), annual BAX card fee (annual_fee) and per-transaction card fee (trans_fee), annual interest rate on deposits (interest_deposit) and interest rate on loans (interest_loan), the number of branch offices (branch), rent costs per branch (rent), wage costs per employee (wage) and payment transmission costs per BAX card transaction (transmission_fee) for four years (2006-2009) distributed across the 19 counties.[24]

Table 7: Issuer side summary statistics – missing information

Issuer variables	**N**	**mean**	**sd**	**max**	**min**	**median**
value_deposit	1822	1,143.61	4174.59	56,594.06	0	18.79
bax_trans	1824	1.32	4.23	57.82	3.56E-4	0.07
bax_value	1824	528.44	1,740.20	21,410.00	0.09	24.21
annual_fee	1805	247.6	26.1	300	150	250
trans_fee	1824	2.1	0.8	4	0	2
interest_deposit	1824	3.2	1.2	5.3	1.5	2.9
interest_loan	1824	5.5	1.2	7.6	3.9	5.1
branch	1824	2	6	57	0	0
wage (in thousand NOK)	1824	477.13	77.83	726.41	340.10	457.73
rent (in million NOK)	1805	1.25	2.17	15.11	0.02	0.61
transmission_fee (in NOK)	1748	2.04	1.42	8.46	0.30	1.84

Notes: Issuer variables: value on deposit accounts (in million NOK), total number of BAX card transactions (in millions), total value of BAX card transactions (in million NOK), prices (in NOK), interest rates (for households) (in %), branch offices, wage costs per employee (in thousand NOK), rent costs per branch (in million NOK), and payment transmission costs per BAX card transaction (in NOK) . source: SSB, Norges Bank (ORBOF) and FNO.

This table first shows that there are some missing values, two missing values in the value on deposit accounts and nineteen in the annual BAX card fee. The two missing values in

[24]We use the prices at the beginning (January 01) of each year. We normalize the cost variables (wage costs, rent costs, payment transmission costs) to calculate variable costs, since we will use them as instruments for prices in our demand estimations.

the value on deposit accounts are from two different banks in two different counties in two different year. One of them is in county 20 in 2008 and the other is in county 17 in 2006. We replace the former with the average of the same bank's deposit account value in the same county over 2007 and 2009, and replace the latter with the same bank's deposit account value in the same county in 2007 because 2006 is the first sample period. The nineteen missing values in the annual BAX card fee are due to another bank not reporting the annual fee for 2007 so the number of the missing values is the same as the number of counties. This bank charged 150 NOK in 2006, 250 NOK in 2008, and 150 NOK in 2009, so a reasonable guess is it charged either 150 NOK or 250 NOK in 2007. Between the two numbers we chose 150 NOK because its value on deposit accounts went up from 2006 to 2007 and then stabilized in 2008. This is just our guess but it seems that this bank experimented with a higher fee in 2008 and then went back to the normal level.

There are also some missing values for the rent and the transmission fee variables. For the rent variable 19 observations are missing due to one bank without the rent information for 2009 (so 19 missing values for 19 counties) and for the transmission fee variable 76 observations are missing due to one bank without this fee information for the whole sample period (so 76 missing values for 19 counties for 4 years). We replace the missing values of the transmission fee with the average fee of the other banks for each year. Because the missing values of the rent variable is only for 2009, we first compare the average rent of the other banks with that of the bank without the 2009 rent information for the years we have data. The ratio of this bank's rent to the national average is 0.45 and 0.44 for 2006 and 2007 respectively and goes up to 0.84 in 2008. We take this increase as a permanent change and replace the missing values with 0.84 of the 2009 national average.

A.2 Acquirer market: Missing values and their imputation

Table 8 describes the acquiring side data. There are three fees that merchants pay for BAX card acceptance services: a one-time fee to register a POS terminal (*POS_reg_fee*), a monthly settlement fee (*POS_settl_fee*), and a BAX card transaction fee (*POS_trans_fee*). We found a non-negligible number of missing values for major variables in our data set. Out of 1,748 observations there are 460 missing values for the number of BAX terminal locations, 430 missing values for the BAX transactions and the value of BAX transactions, 912 missing values for the registration fee and the settlement fee, and 836 missing values for the transaction fee. However, it is not clear to us whether these missing values are really missing values or zeros. For example, if a bank does not have any POS terminal in a county, this could be left as blank, which makes it look like a missing value. Thus, we compared

Table 8: Acquirer side summary statistics

Acquirer Variables	**N**	**mean**	**sd**	**max**	**min**	**median**
POS_location_BAX	1288	222.6	590.9	6,402	0	8
bax_trans (in millions)	1318	2.02	5.85	71.13	0	0.03
bax_value (in billion NOK)	1318	0.81	2.34	24.29	0	0.02
POS_reg_fee	836	518.18	24.07	550	500	500
POS_settl_fee	836	142.84	36.33	240	60	150
POS_trans_fee	912	0.17	0.38	2	0	0.15
interest_loan_corp	1729	6.03	1.29	9	3.82	5.87
interest_deposit_corp	1729	3.35	1.26	5.71	1.44	3

Notes: Acquiring banks' POS locations accepting BAX cards, total number of BAX card transactions (in millions), total value of BAX card transactions (in million NOK), BAX fees for merchants (in NOK) and interest rates for merchants (in %). source: BBS, SSB and Norges Bank.

county-level total BAX transaction from the merchant (acquirer) side with that from the issuer side. The comparison shows that 430 missing values for the BAX transactions are not missing values but zeros. In 2006, for example, the average number of BAX transactions per county is recorded as 28.33 millions on the issuer side and 31.04 millions on the acquirer side. The average value of BAX transactions per county is 11.68 billions on the issuer side and 12.79 billions on the acquirer side. There are some discrepancies but the difference is about 10%, and more importantly the acquirer side reports higher numbers. Thus, we conclude it would be reasonable to assume that these missing values are actually zeros.

If this assumption were correct, the banks on average do not have any POS terminals in 7 counties out of 19. Only 6 banks have POS terminals in all 19 counties and a few banks have POS terminals in less than 5 counties. However, the bank-level correlation between the merchant-side BAX transaction and the consumer-side BAX transaction is over 0.95, meaning that no bank dominates only on one side.

The 912 missing values for the registration fee and the settlement fee are due to a half of the banks (12 banks) not reporting their merchant fees in the survey. However, this number is not as high as it seems once the banks that do not have POS terminals in some counties are counted for. Out of the 912 missing values 387 observations do not record any BAX transaction activities (that is, zero value for BAX transactions), so the number of relevant missing values is 525.

Moreover, the 12 banks that do not report the fees are not major banks in any dimensions. These banks own 27% of POS terminals throughout the country and the amount of BAX transactions processed at these terminals is less than 30% both in terms of the number and the value.

B Consumer bank choice and card usage

B.1 Aggregating consumer-level card usage demand to bank-level card usage demand

In the following example we illustrate how we define card usage bank-level card usage shares by aggregating consumer-level card usage demands. We illustrate why we need to account for the distribution of consumer types conditional bank choice when we do this aggregation.

Consider two types (1 and 2) and two banks (A, B), and one county. Let N denote the total number of potential consumers in the market, N_j denote the number of customers of bank j, s_j denote the market share of bank j for value on deposit accounts in the county, for $j \in \{A, B\}$. We assume that each bank's market share for cardholders is the same as its market share for value on deposit accounts, and so we have

$$N_j = N s_j \tag{16}$$

Moreover, let N_{ij} denote the number of type i customers of bank j, for $i \in \{1, 2\}$, so $N_j = N_{1j} + N_{2j}$ for $j \in \{A, B\}$. We assume that the total number of payment transactions (including card, cash, etc.) made by each type i customer of bank j is the same and equal to R_{ij}. Finally, we assume that the total number of debit card transactions made by each type i customer of bank j is the same and equal to D_{ij}. Our model for card usage then implies that type i consumer's total usage of bank j's card is equal to their probability of paying by card j times the total number of all payment transactions she makes:

$$D_{ij} = \frac{\exp(\delta_j - \alpha_i f_j)}{1 + \exp(\delta_j - \alpha_i f_j)} R_{ij} N_{ij}$$

We could then write the total card transaction volume of bank j as the sum of card transactions made by its customers of type 1 and 2:

$$D_j = \sum_{i=1,2} \Big(\frac{\exp(\delta_j - \alpha_i f_j)}{1 + \exp(\delta_j - \alpha_i f_j)} R_{ij} N_{ij} \Big) \tag{17}$$

We assume that within a county customers of a given bank make the same number of total transactions regardless of their type: $R_{1j} = R_{2j} \equiv r_j$. Under this assumption total payment transactions made by bank j's customers is equal to $R_j = N_j r_j$. Let s^u_j denote bank j's total card usage share over the total amount of payment transactions made by its customers: $s_j^u = \frac{D_j}{R_j}$. Using equation (17) we then rewrite bank j's card usage share as

$$s_j^u = \sum_{i=1,2} \left(\frac{\exp(\delta_j - \alpha_i f_j)}{1 + \exp(\delta_j - \alpha_i f_j)} \frac{N_{ij}}{N_j} \right)$$

We can rewrite the proportion of type i customers over the total customers of bank j as the ratio of the probability that type i customers choosing bank j over the probability of both types choosing bank j :

$$\begin{aligned} \frac{N_{ij}}{N_j} &= \frac{N_{ij}/N}{N_j/N} = \frac{\frac{N_{ij}}{N_i}\frac{N_i}{N}}{\frac{N_{1j}}{N_1}\frac{N_1}{N} + \frac{N_{2j}}{N_2}\frac{N_2}{N}} = \frac{Pr(i \in j|i)Pr(i)}{Pr(1 \in j|1)Pr(1) + Pr(2 \in j|2)Pr(2)} \\ &= \frac{Pr(i \in j)}{Pr(1 \in j) + Pr(2 \in j)} = w_{ij} \end{aligned}$$

We then rewrite bank j's card usage share as

$$s_j^u = \sum_{i=1,2} \left(\frac{\exp(\delta_j - \alpha_i f_j)}{1 + \exp(\delta_j - \alpha_i f_j)} w_{ij} \right). \tag{18}$$

Hence, we conclude that when we have a continuum of consumer types, the share of bank j card transactions over the total of payment transactions made by its customers in market t is given by

$$s_{jt}^u = \int \left(\frac{\exp(\delta_j - \alpha_i f_j)}{1 + \exp(\delta_j - \alpha_i f_j)} w_{ij} \right) d\alpha_i. \tag{19}$$

where

$$w_{ij} = \frac{Pr(i \in j)}{\sum_s Pr(s \in j)}$$

By definition $\sum_i w_{ij} = 1$ for all j, so w_{ij} represents an economically and analytically meaningful weight multiplying type i's usage probability of card j. This weight accounts for the fact that for each consumer, we use the same type (marginal disutility of money) at the bank choice and card usage decision, so each type has a different likelihood of choosing bank j.

B.2 Approximating the number of total transactions made by bank j's customers

When a consumer makes a purchase by using her debit card, the corresponding value of purchase is deducted from her deposit account immediately. We argue that the total amount of money used for POS purchases is the sum of debit card usage and a fraction of the money in her deposit account. Hence, the total POS number transactions (purchase volume) of bank j customers in market t is equal to

$$R_{jt} = D_{jt} + \frac{wV_{jt}}{v_{jt}}$$

where w denotes the share of the value on deposit accounts that customers use to make purchases at POSs, D_{jt} the total number of BAX card transactions, and V_{jt} denotes the deposit value. The average value of a BAX-transaction of bank j's customers in market t is $v_{jt} = D^V_{jt}/D_{jt}$, where D^V_{jt} is the total value of BAX card transactions made by customers of bank j in market t. By dividing deposit value, V_{jt}, by v_{jt}, we convert the value of transactions to the number of transactions. In doing so we implicitly assume that the average value of a BAX-transaction of bank j customers in market t is the same as the average value of any payment transaction of bank j customers in market t.[25]

We do not observe w, so we make use of data taken from the POS survey. In particular, we observe the debit card share over all transactions for each county that occurred on the day before the survey was conducted. We find w which minimizes the distance between county level mean debit card usage shares calculated using the bank level data,

$$\frac{1}{J}\sum_j \frac{D_{jt}}{\hat{R}_{jt}} = \sum_j \frac{D_{jt}}{D_{jt} + \frac{\hat{w}V_{jt}}{v_{jt}}}$$

and the county-level debit card usage shares estimated from the POS survey data. The estimate $\hat{R}_{jt}$ approximates the number of total transactions by bank j's customers in market t.

B.3 Calculation of the share of BAX debit card service fees over costs of other relevant services

Here we aim to calculate what percentage of the total costs of retail banking services correspond to BAX card fees for an average customer of a given bank in a given year from 2006 to 2008. To do that we need to use data on total usage volume (transactions) and prices of different retail banking services, and the total number of customers of a given bank in a given year. These services are BAX debit card membership, BAX debit card usage, usage of internet banking solutions, ATM withdrawals from own bank ATMs, ATM withdrawals

[25] If customers use BAX card more often for high value transactions, then we might have a downward bias in calculating the total number of transactions and so might over-estimate the convenience benefit from paying by BAX rather than cash. From the survey data we verify that the average value of a BAX card transaction is not statistically different from the average value of cash transaction.

from other banks' ATMs, direct debit usage (avtalegiros and autogiros).

We first define our notation for important variables. Let N_{jt} denote the total number of BAX card customers of bank j, Φ_{jt} denote the total annual costs of using bank j's retail banking services, ϕ_{jt} denote the annual cost of bank j's average customer from using retail banking services, S_j denote the set of bank j's retail banking services, q_{ijt} denote the volume of transactions of service i of bank j, p_{ijt} is the unit price of service i of bank j for year $t \in \{2006, 2007, 2008\}$. There is only one membership service (having a debit card agreement). In that case the quantity variable is equal to the number of BAX card customers: $q_{ijt} = Njt$.

Using the data on service transaction volumes (usage) and prices for the above services, we calculate first the total costs of using bank j's services by

$$\Phi_{jt} = \sum_{i \in S_{jt}} q_{ijt} p_{ijt} \tag{20}$$

Using the data on the total number of customers per bank we next calculate the cost of using bank j's services for an average customer by diving the total costs by the total number of bank j's BAX card customers:

$$\phi_{jt} = \frac{\Phi_{jt}}{N_{jt}}. \tag{21}$$

We then calculate the annual cost of BAX card services for an average customer of bank j by

$$\phi_{baxjt} = F_{jt} + \frac{f_{jt} q_{baxjt}}{N_{jt}}. \tag{22}$$

where F_{jt} is the annual BAX card fee, f_{jt} is the BAX card transaction fee, and q_{baxjt} is the total volume of BAX card transactions of bank j in year t.

We finally calculate the share of BAX card fees over the total costs by

$$costsharebax_{jt} = \frac{\phi_{baxjt}}{\phi_{jt}} 100. \tag{23}$$

B.3.1 Correlation between consumer prices

In Table 9 we report the pairwise correlation between banks' prices for different retail banking services for consumers. Debit card services have two prices: Annual card fee (card_fee) and card transaction fee (card_trans). Cash withdrawals from ATMs have two prices: atm_home refers to the fee of withdrawing cash from own bank's ATMs and atm_other refers to the fee of withdrawing cash from other banks' ATMs. The fee of paying by electronic invoice is efact_fee, the fee of internet banking solutions is net_fee and the fee of direct debit payments is giro_fee.

Table 9: Correlations of fees across issuer bank services

Prices	card_fee	card_trans	atm_home	atm_other	efact_fee	net_fee	giro_fee
card	1						
card_trans	-0.22	1					
atm_home	-0.3	0.59	1				
atm_other	-0.1	0.64	0.43	1			
efact_fee	-0.12	0.79	0.56	0.66	1		
net_fee	-0.12	0.70	0.56	0.64	0.92	1	
giro_fee	-0.05	0.35	0.40	0.69	0.57	0.63	1

As the table shows that the correlation between annual card fee and the other retail banking services' fees are negative and very low (see the numbers in the second column). On the other hand, the correlation between card transaction fee and other retail banking services' fees are positive and rather high (see the numbers in the third column). In particular, the correlation between card transaction fee and e-invoice fee is 0.8 and the correlation between card transaction fee and internet fee is 0.7.

C Merchant bank choice

C.1 Homogenous merchants and redundancy of two-part tariffs

Suppose that in a given county merchants are homogenous and process the same volume of card transactions. Let π_{ijt} denote the utility of merchant i which is located in market t and uses the acquiring services of bank j:

$$\pi_{ijt} = x_{jt}\lambda - \mu(M_{jt} + m_{jt}\frac{D_t}{N_t^S}) + \zeta_{jt} + \varepsilon_{ijt} \tag{24}$$

This utility depends on the acquirer bank's characteristics, x_{jt}, monthly merchant fee, M_{jt}, per-transaction merchant fee, m_{jt}, as well as the other characteristics of the acquirer, ζ_{jt}, which are observed by the merchant and acquirer, but not observed by the econometrician. Let ε_{ijt} denote random taste shocks on the merchant's utility. Note that per-transaction merchant fee's impact on the merchant's utility is proportional to the amount of card transactions the merchant expects to have in that market, $\frac{D_t}{N_t^S}$, where D_t is the total card transaction volume in market t.

In every period each bank earns the issuer profits from card transactions made by its cardholders in all counties as well as the acquirer profits from card transactions settled at its merchant locations in all counties. Like in section 5.3 we change the notation and denote county by c, and time by t. Recall that the reason of the notation change is to analyse the bank's problem while taking into account the fact that in a given year each bank sets the same fees in all counties (national pricing policy). We drop the subscript for time, t, to simplify the notation. Let D_{jc} denote the volume of card transactions processed by a merchant located at county c and acquired by bank j. Merchant homogeneity assumption implies that this merchant processes the average volume of card transactions in county c, that is, $D^S_{jc} = \frac{D_c}{N^S_c}$, where D_c is the total volume of card transactions processed in county c and N^S_c is the total number of merchants in county c. But then the total volume of card transactions processed by all merchants of bank j in county c is equal to $\sum_c D^S_{jc} N^S_{jc}$, where N^S_{jc} denote the total number of merchants acquired by bank j in county c. Using $D^S_{jc} = \frac{D_c}{N^S_c}$ we rewrite the total volume of card transactions processed by all merchants of bank j in county c as $\sum_c D_c s^S_{jc}$, where s^S_{jc} refers to the bank's market share on the merchant side: $s^S_{jc} = \frac{N^S_{jc}}{N^S_c}$. Bank j's profit is then

$$\Pi_j = \Pi^I_j + \Pi^A_j = \sum_c [(f_j - c^I_j) D_{jc} N^B_c s^B_{jc} + (F_j - C^I_j) N^B_c s^B_{jc} + (m_j - c^A_j) D_c s^S_{jc} + (M_j - C^A_j) N^S_c s^S_{jc}].$$

The first term corresponds to the variable issuer profits from card transactions settled by bank j's cardholders: the variable issuer margin, $f_j - c^I_j$, times the total card usage demand of its cardholders in all counties, $\sum_c D_{jc} N^B_c s^B_{jc}$, where D_{jc} is card usage demand of a cardholder of bank j in county c and $N^B_c s^B_{jc}$ corresponds to the total number of the bank's cardholders in county c given that s^B_{jc} refers to the bank's market share over cardholders: $s^B_{jc} = \frac{N^B_{jc}}{N^B_c}$ and N^B_c refers to the total market size on the consumer side. The second term of the bank's profit expression corresponds to the fixed (with respect to transactions) margin from the bank's cardholders. The third term corresponds to the variable acquirer profits from card transactions settled at the merchant locations that are the customers of the bank: the variable acquirer margin, $m_j - c^A_j$, times the total volume of card transactions processed by all merchant locations acquired by the bank in county c, $\sum_c D_c s^S_{jc}$. Finally, the fourth term corresponds to the fixed acquirer margin from the bank's merchants. Bank j maximises its profit with respect to four different prices, f_j, F_j, m_j, M_j. The optimal prices of bank j are determined by the following first-order conditions:

$$FOC_{f_j}: \sum_c [D_{jc}N_c^B s_{jc}^B + (f_j - c_j^I)N_c^B \left(\frac{dD_{jc}}{df_j}s_{jc}^B + D_{jc}\frac{ds_{jc}^B}{df_j}\right) + (F_j - C_j^I)N_c^B \frac{ds_{jc}^B}{f_j} + (m_j - c_j^A)\left(s_{jc}^S \frac{dD_c}{df_j} + D_c \frac{ds_{jc}^S}{df_j}\right) + (M_j - C_j^A)N_c^S \frac{ds_{jc}^S}{df_j}] = 0$$

$$FOC_{F_j}: \sum_c [N_c^B s_{jc}^B + (f_j - c_j^I)N_c^B D_{jc}\frac{ds_{jc}^B}{dF_j} + (F_j - C_j^I)N_c^B \frac{ds_{jc}^B}{dF_j}] = 0$$

$$FOC_{m_j}: \sum_c [D_c s_{jc}^S + (m_j - c_j^A)D_c \frac{ds_{jc}^S}{dm_j} + (M_j - C_j^A)N_c^S \frac{ds_{jc}^S}{dm_j}] = 0$$

$$FOC_{M_j}: \sum_c [N_c^S s_{jc}^S + (m_j - c_j^A)D_c \frac{ds_{jc}^S}{dM_j} + (M_j - C_j^A)N_c^S \frac{ds_{jc}^S}{dM_j}] = 0$$

In this model the merchants fees can not be identified separately because what matters for the merchants' bank choice and the banks' profits is the average merchant fee: for a given average merchant fee of a bank, the level of transaction fee or fixed fee does not affect the merchant demand or bank profit. There are two reasons of the redundancy of non-linear prices on the merchant side: 1. In a given county and year all merchants have exactly the same amount of card transactions (by assumption of merchant homogeneity), 2. Merchants cannot influence the card transaction volume (due to the fact that consumers are the ones that decide whether to check out by card or not). To illustrate the redundancy of non-linear merchant fees we consider the optimality conditions for merchant fees of a bank that is active in only one county and we dropped subscript for county, c:

$$FOC_{m_j}: D s_j^S + (m_j - c_j^A)D\frac{ds_j^S}{dm_j} + (M_j - C_j^A)N^S \frac{ds_j^S}{dm_j} = 0 \tag{25}$$

$$FOC_{M_j}: N^S s_j^S + (m_j - c_j^A)D\frac{ds_j^S}{dM_j} + (M_j - C_j^A)N^S \frac{ds_j^S}{dM_j} = 0 \tag{26}$$

Using the merchant's profit expression, (24), it is straightforward to derive the equivalence between the reaction of merchant demand to the transaction fee and the reaction of merchant demand to the fixed fee:

$$\frac{ds_j^S}{dm_j} = \frac{D}{N^S}\frac{ds_j^S}{dM_j}$$

But then if we replace this into the first-order condition for m_j, (25), we obtain exactly the first-order condition for M_j, (26). Hence, this condition determines the optimal relationship between the fixed and transaction merchant fees and the bank is indifferent between the different levels of these fees as long as this condition holds, that is, the optimal merchant fees can not be identified separately.

On the other hand, using non-linear merchant fees, the banks that are active in more than one county can discriminate between merchants from different counties if these counties have different amount of card transaction volume per merchant. In these cases the first-order conditions over-identify merchant fees. To illustrate this we consider the optimality conditions for merchant fees of a bank that is active in two counties, 1 and 2:

$$\begin{aligned} FOC_{m_j} : D_1 s_{j1}^S + D_2 s_{j2}^S + (m_j - c_j^A) D_1 \frac{ds_{j1}^S}{dm_j} + (m_j - c_j^A) D_2 \frac{ds_{j2}^S}{dm_j} + \\ (M_j - C_j^A) N_1^S \frac{ds_{j1}^S}{dm_j} + (M_j - C_j^A) N_2^S \frac{ds_{j2}^S}{dm_j} = 0. \end{aligned}$$

$$\begin{aligned} FOC_{M_j} : N_1^S s_{j1}^S + N_2^S s_{j2}^S + (m_j - c_j^A) D_1 \frac{ds_{j1}^S}{dM_j} + (m_j - c_j^A) D_2 \frac{ds_{j2}^S}{dM_j} + \\ (M_j - C_j^A) N_1^S \frac{ds_{j1}^S}{dM_j} + (M_j - C_j^A) N_2^S \frac{ds_{j2}^S}{dM_j} = 0. \end{aligned}$$

Similar to the previous case we can use (24) to derive the equivalence between the reaction of merchant demand in each county to the transaction fee and to the fixed fee, for $c = 1, 2$:

$$\frac{ds_{jc}^S}{dm_j} = \frac{D_c}{N_c^S}\frac{ds_{jc}^S}{dM_j}$$

Replacing this into the first-order condition for m_j we rewrite the latter as

$$FOC_{m_j}: \frac{D_1}{N_1^S}\left(N_1^S s_{j1}^S + (m_j - c_j^A)D_1\frac{ds_{j1}^S}{dM_j} + (M_j - C_j^A)N_1^S\frac{ds_{j1}^S}{dM_j}\right) +$$
$$\frac{D_2}{N_2^S}\left(N_2^S s_{j2}^S + (m_j - c_j^A)D_2\frac{ds_{j2}^S}{dM_j} + (M_j - C_j^A)N_2^S\frac{ds_{j2}^S}{dM_j}\right) = 0$$

Observe that this condition cannot hold together with the first-order condition for M_j except for one specific case where the average card transaction per merchant is the same in both counties, $\frac{D_1}{N_1^S} = \frac{D_2}{N_2^S}$ (recall that the average card transaction per merchant is exogenous, that is, the bank cannot influence it by its choice of merchant fees). Even in that particular case transaction and fixed merchant fees cannot be identified separately since the two first-order conditions would then be the same equation.

C.2 Illustration: Merchant heterogeneity and identification of two-part merchant fees

To illustrate the identification of merchant fees when there is merchant heterogeneity consider a bank, say bank j, which is active in only one county and drop county identifier to simplify expressions. The profit of the bank will be

$$\Pi_j = (f_j - c_j^I)D_j N^B s_j^B + (F_j - C_j^I)N^B s_j^B + (m_j - c_j^A)D\sum_k N_k^S w_k s_{kj}^S + (M_j - C_j^A)\sum_k N_k^S s_{kj}^S.$$

The bank's first-order conditions with respect to m_j and M_j will be

$$FOC_{m_j}: \sum_k\left[DN_k^S w_k s_{kj}^S + (m_j - c_j^A)N_k^S w_k\frac{ds_{kj}^S}{dm_j} + (M_j - C_j^A)N_k^S\frac{ds_{kj}^S}{dm_j}\right] = 0$$
$$FOC_{M_j}: \sum_k\left[N_k^S s_{kj}^S + (m_j - c_j^A)DN_k^S w_k\frac{ds_{kj}^S}{dM_j} + (M_j - C_j^A)N_k^S\frac{ds_{kj}^S}{dM_j}\right] = 0$$

Using equation (6) for one county we derive

$$\frac{ds_{kj}^S}{dm_j} = w_k D\frac{ds_{kj}^S}{dM_j}$$

and replacing the latter into FOC_{m_j} we rewrite the latter as

$$FOC_{m_j} : D\sum_k w_k \left[N_k^S s_{kj}^S + (m_j - c_j^A) D N_k^S w_k \frac{ds_{kj}^S}{dM_j} + (M_j - C_j^A) N_k^S \frac{ds_{kj}^S}{dM_j} \right] = 0$$

which is not co-linear with the FOC_{M_j} and so the merchant fees (M_j, m_j) can be identified separately.

C.3 An example of how to identify merchant type-specific market shares and their derivatives

Consider the example of a market with 2 banks in our sample and the outside option, so $j \in \{0, 1, 2\}$.

Step 1: Calculate merchant type specific market shares In this example we will have 8 equations from system (9)-(11) for all $j \in \{0, 1, 2\}$ and $k \in \{A, B\}$:

$$\begin{aligned} w_A N_{A0}^S + w_B N_{B0}^S &= D_0^S & (27)\\ w_A N_{A1}^S + w_B N_{B1}^S &= D_1^S & (28)\\ w_A N_{A2}^S + w_B N_{B2}^S &= D_2^S & (29)\\ N_{A0}^S + N_{B0}^S &= N_0^S & (30)\\ N_{A1}^S + N_{B1}^S &= N_1^S & (31)\\ N_{A2}^S + N_{B2}^S &= N_2^S & (32)\\ N_{A0}^S + N_{A1}^S + N_{A2}^S &= N_A^S & (33)\\ N_{B0}^S + N_{B1}^S + N_{B2}^S &= N_B^S. & (34) \end{aligned}$$

which we can solve to identify the vector of 8 unknowns: $[w_A, w_B, N_{A0}^S, N_{B0}^S, N_{A1}^S, N_{B1}^S, N_{A2}^S, N_{B2}^S]$.

Step 2: Calculate merchant type specific market share derivatives In this example, we have 8 equations from (9)-(11):

$$\begin{aligned}
\frac{dw_A}{df_m}N^S_{A0} + w_A\frac{dN^S_{A0}}{df_m} + \frac{dw_B}{df_m}N^S_{B0} + w_B\frac{dN^S_{B0}}{df_m} &= \frac{dD^S_0}{df_m}, && (35)\\
\frac{dw_A}{df_m}N^S_{A1} + w_A\frac{dN^S_{A1}}{df_m} + \frac{dw_B}{df_m}N^S_{B1} + w_B\frac{dN^S_{B1}}{df_m} &= \frac{dD^S_1}{df_m}, && (36)\\
\frac{dw_A}{df_m}N^S_{A2} + w_A\frac{dN^S_{A2}}{df_m} + \frac{dw_B}{df_m}N^S_{B2} + w_B\frac{dN^S_{B2}}{df_m} &= \frac{dD^S_2}{df_m}, && (37)\\
\frac{dN^S_{A0}}{df_m} + \frac{dN^S_{B0}}{df_m} &= \frac{dN^S_0}{df_m}, && (38)\\
\frac{dN^S_{A1}}{df_m} + \frac{dN^S_{B1}}{df_m} &= \frac{dN^S_1}{df_m}, && (39)\\
\frac{dN^S_{A2}}{df_m} + \frac{dN^S_{B2}}{df_m} &= \frac{dN^S_2}{df_m}, && (40)\\
\frac{dN^S_{A0}}{df_m} + \frac{dN^S_{A1}}{df_m} + \frac{dN^S_{A2}}{df_m} &= \frac{dN^S_A}{df_m}, && (41)\\
\frac{dN^S_{B0}}{df_m} + \frac{dN^S_{B1}}{df_m} + \frac{dN^S_{B2}}{df_m} &= \frac{dN^S_B}{df_m}. && (42)
\end{aligned}$$

We compute merchant side market shares using calculated w_k (from Step 1 of the example) and equation (7) for every $j \in \{0, 1, 2\}$:

$$s^S_{k0} = \frac{1}{1 + \sum_{j=1}^{2} exp\left(x_j\lambda + \zeta_j - \mu(M_j + m_j w_k\right)} \tag{43}$$

$$s^S_{k1} = \frac{exp\left(x_1\lambda + \zeta_1 - \mu(M_1 + m_1 w_k)\right)}{1 + \sum_{j=1}^{2} exp\left(x_j\lambda + \zeta_j - \mu(M_j + m_j w_k\right)}, \tag{44}$$

$$s^S_{k2} = \frac{exp\left(x_2\lambda + \zeta_2 - \mu(M_2 + m_2 w_k)\right)}{1 + \sum_{j=1}^{2} exp\left(x_j\lambda + \zeta_j - \mu(M_j + m_j w_k\right)}, \tag{45}$$

Then deriving both sides of each equation in the previous system for all $k \in \{A, B\}$

gives us 6 more equations:

$$\frac{ds^S_{A0}}{df_m} = -\mu m_m \frac{dw_A}{df_m} s^S_{A0}\left(1 - s^S_{A0}\right), \tag{46}$$

$$\frac{ds^S_{A1}}{df_m} = -\mu m_m \frac{dw_A}{df_m} s^S_{A1}\left(1 - s^S_{A1}\right), \tag{47}$$

$$\frac{ds^S_{A2}}{df_m} = -\mu m_m \frac{dw_A}{df_m} s^S_{A2}\left(1 - s^S_{A2}\right), \tag{48}$$

$$\frac{ds^S_{B0}}{df_m} = -\mu m_m \frac{dw_B}{df_m} s^S_{B0}\left(1 - s^S_{B0}\right), \tag{49}$$

$$\frac{ds^S_{B1}}{df_m} = -\mu m_m \frac{dw_B}{df_m} s^S_{B1}\left(1 - s^S_{B1}\right), \tag{50}$$

$$\frac{ds^S_{B2}}{df_m} = -\mu m_m \frac{dw_B}{df_m} s^S_{B2}\left(1 - s^S_{B2}\right). \tag{51}$$

Solving the latter equations (46)-(51) together with equations (35)-(42) we can identify the vector of 14 unknowns:

$$[\frac{dw_A}{df_m}, \frac{dw_B}{df_m}, \frac{dN^S_{A0}}{df_m}, \frac{dN^S_{B0}}{df_m}, \frac{dN^S_{A1}}{df_m}, \frac{dN^S_{B1}}{df_m}, \frac{dN^S_{A2}}{df_m}, \frac{dN^S_{B2}}{df_m}, \frac{dN^S_0}{df_m}, \frac{dN^S_1}{df_m}, \frac{dN^S_2}{df_m}, \frac{dD^S_0}{df_m}, \frac{dD^S_1}{df_m}, \frac{dD^S_2}{df_m}].$$

D Estimation

D.1 Hedonic transaction fee regressions

In order to see what bank characteristics explain differences in the BAX card fees, we run hedonic regressions for the BAX annual fee and the BAX transaction fee on demand and cost variables. Table 10 reports banks' cost variables: Wage refers to the total wage costs per employee, rent refers to total rent costs per branch and transmission_fee refers total transmission fees (which are fees paid to other banks for various payment transmissions) per BAX card transaction. Because the fees and the cost variables do not vary across the counties, we run bank-level regressions with 96 observations (24 banks for 4 years). The main demand variable is the branch variable which is a good proxy for the degree of market dominance in each county, and we sum them up across the counties and use the total number of branches as the demand variable. For the cost variables we use wages per employee, rent per branch, and transmission fees per BAX card transactions.

Table 11 shows the results from regressing the BAX fees (the annual BAX card fee and the per-transaction fee) on the total number of branches and the three cost variables. For each price we run three regressions, the first without the year or the bank fixed effects, the

Table 10: Banks costs summary statistics

Cost variables	**N**	**mean**	**sd**	**max**	**min**	**median**
wage (in thousand NOK)	1824	477.13	77.83	726.41	340.10	457.73
rent (in million NOK)	1824	1.25	2.16	15.11	0.02	0.62
transmission_fee (in NOK)	1824	2.04	1.39	8.46	0.30	1.90

Notes: The variables in this table are wage costs per employee (in thousand NOK), rent costs per branch (in million NOK), and payment transmission costs per BAX card transaction (in NOK). source: Norges Bank (ORBOF) and Finance Norway.

second with the year fixed effects but without the bank fixed effects, and the third with both the year and the bank fixed effects. So Table 11 reports results from these six regressions.

First notice that much of variations in the BAX fees are explained by unobserved bank-level differences. The R-square only goes up from 0.09 to 0.15 after adding the year fixed effects for the BAX annual fee and from 0.32 to 0.33 for the transaction fee, but it goes up to 0.72 and 0.78 respectively after adding the bank fixed effects.

The table shows that the number of branches is positively correlated with the BAX fees without the bank fixed effects but becomes statistically insignificant once the bank fixed effects are included. This means that the total number of branches does not explain fee differences more than what the bank fixed effects do. However, the cost variables have more explanatory power than the branch variable. The wage variable is negatively correlated with the BAX annual fee even after adding the bank fixed effects, implying that banks with higher labor costs tend to charge lower annual fees. The transmission fee is also correlated with the BAX annual fee, but the sign of the correlation changes from negative to positive after adding the bank fixed effects. The rent variable is negatively correlated with the BAX transaction fee without the bank fixed effects but becomes statistically insignificant once the bank fixed effects are added although the sign remains negative. The BAX transaction fee is not correlated with the other two cost variables even without the bank fixed effects. These results suggest that differences in the BAX annual fee reflect cost differences among the banks rather than their market power or demand-related factors. This is a good news for demand estimation because (1) the price endogeneity issue is not likely to be prominent and (2) if we are concerned with the price endogeneity the cost-side variables can be used as instruments at least for the BAX annual fee.[26]

These findings are consistent with the evidence from the Internet Banking Survey (2009)

[26]We also ran hedonic regressions for other fees we have data on and found that almost all of them were highly correlated with the cost variables controlling for the year and the bank fixed effects.

Table 11: Hedonic Regressions for BAX Fees

	(1) annual_fee	(2) annual_fee	(3) annual_fee	(4) trans_fee	(5) trans_fee	(6) trans_fee
constant	281.881***	301.793***	364.792***	2.190***	2.054***	0.942
	(19.859)	(22.706)	(65.264)	(0.482)	(0.570)	(1.619)
total number of branches	0.193***	0.219***	0.060	0.006***	0.006***	-0.001
	(0.077)	(0.077)	(0.308)	(0.002)	(0.002)	(0.008)
wage	-77.436**	-108.687***	-185.143***	0.038	0.195	-1.934
	(44.890)	(46.835)	(86.580)	(1.089)	(1.175)	(2.147)
rent	1.463	1.413	-4.055	-0.179***	-0.178***	-0.006
	(1.318)	(1.295)	(3.307)	(0.032)	(0.033)	(0.082)
transmission fee	-3.662*	-3.540*	8.756*	-0.070	-0.073	-0.024
	(2.362)	(2.327)	(6.392)	(0.057)	(0.058)	(0.159)
Year FE	No	Yes	Yes	No	Yes	Yes
Bank FE	No	No	Yes	No	No	Yes
N	96	96	96	96	96	96
R^2	0.090	0.152	0.715	0.323	0.326	0.778

Standard errors in parentheses

* $p < 0.20$, ** $p < 0.10$, *** $p < 0.05$

conducted by the Norwegian Savings Banks Association (SPF).[27] The survey finds that the most important two criterion when choosing a particular bank are 1) bank having a branch in the customer's neighborhood (25%), 2) price (18%).[28] Other factors such as service and that "the bank knows me" are also found nearly as important as price. Customers have been mostly loyal to their main bank[29] and nearly half (42%) of the respondents were in loyalty programs. On the other hand, a significant majority (76%) stated that switching to another bank is very easy, regardless of the fact that customers are in a loyalty program or not. Prices/fees and interest rates on loans are named as the two main drivers of changing the main bank in Norway.[30]

Less and less people withdrew cash from ATMs[31] and/or stores.[32] This reduction in cash withdrawals can be associated to the increasing use of payment cards in Norway. In 2009 44% of the customers used card each time they purchased groceries and this is 10% more than 2005. In particular consumers of age 20-50 have been the frequent card users. The main advantages of using card rather than cash are stated to be: 1) no need to carry cash (62%), 2) easier (25%), and 3) safer (11%). The most important benefits of paying by cash are named to be: 1) do not have to pay fees (23%), 2) better consumption/expense control (15%). Against the expectations a high majority of customers (80%) claim that they pay high attention to the conditions of their payment methods, 93% of those between 25-32 years stated that they compare prices of different banks.

[27] This survey interviews 1000 persons over 15 years old by phone. The market analysis company TNS Gallup conducted the survey on behalf of Sparebankforeningen. This survey is conducted each year since 2000.

[28] Branch network being the most important criteria for a consumer's bank choice is despite the fact that use of branch banking services have been decreasing in Norway. In 2009 only 28% of customers visited branch offices at least once a month, compared to 34% in 2008. The branch office network is highly correlated to ATM network, so the importance of the branch network for bank choice might also reflect the importance of ATM network for bank choice, in particular, because ATM withdrawal fees from ATMs of other banks are high in Norway.

[29] 83% of customers said that they used the same main bank in the last five years or more, and loyalty was highest amongst the customers above 50 years.

[30] 29% of consumers mention prices/fees and 25% of consumers mention the interest rates on loans as main drivers of changing their bank. These percentages were 41% and 21% in 2008.

[31] 49% in 2005 withdrew cash from ATMs at least once a week and this number was only 34% in 2009.

[32] In Norway consumers can withdraw cash (cash-backs) from stores' POS terminals using their cards. In 2005 57% used cash-backs at least once a week and only 41% did this in 2009.

E Issuer-side market share derivatives

E.1 With respect to card usage fee f_{jt}

E.1.1 Card usage

$$\frac{ds^u_{jt}}{df_{jt}} \approx \sum_i \left\{ -\alpha_i s^u_{ijt}(1-s^u_{ijt}) \frac{s_{ijt}}{\sum_i s_{ijt}} + s^u_{ijt} \left[\frac{ds_{ijt}}{df_{jt}} \frac{1}{\sum_i s_{ijt}} - s_{ijt} \sum_i \frac{ds_{ijt}}{df_{jt}} \frac{1}{(\sum_i s_{ijt})^2} \right] \right\}$$

where

$$\frac{ds_{ijt}}{df_{jt}} = \frac{db_{ijt}E[D_{ijt}]}{df_{jt}} \left[s_{ijt}(1-s_{ijt}) \right], \tag{52}$$

$$\frac{db_{ijt}E[D_{ijt}]}{df_{jt}} = \left\{ -\frac{\alpha_i exp(\delta_{jt}-\alpha_i f_{jt})}{1+exp(\delta_{jt}-\alpha_i f_{jt})} s^u_{ijt} + \log[1+exp(\delta_{jt}-\alpha_i f_{jt})] \frac{ds^u_{ijt}}{df_{jt}} \right\} \frac{\hat{R}_{jt}}{N_{jt}} \tag{53}$$

$$= \left\{ -\alpha_i (s^u_{ijt})^2 + \log[1+exp(\delta_{jt}-\alpha_i f_{jt})] \frac{ds^u_{ijt}}{df_{jt}} \right\} \frac{\hat{R}_{jt}}{N_{jt}}, \tag{54}$$

and

$$\frac{ds^u_{ijt}}{df_{jt}} = -\alpha_i s^u_{ijt}(1-s^u_{ijt}). \tag{55}$$

Plugging (55) in (54):

$$\frac{db_{ijt}E[D_{ijt}]}{df_{jt}} = -\alpha_i s^u_{ijt} \left\{ s^u_{ijt} + \log[1+exp(\delta_{jt}-\alpha_i f_{jt})](1-s^u_{ijt}) \right\} \frac{\hat{R}_{jt}}{N_{jt}} \tag{56}$$

and (56) in (52):

$$\frac{ds_{ijt}}{df_{jt}} = -\alpha_i s^u_{ijt} \left[s_{ijt}(1-s_{ijt}) \right] \left\{ s^u_{ijt} + \log[1+exp(\delta_{jt}-\alpha_i f_{jt})](1-s^u_{ijt}) \right\} \frac{\hat{R}_{jt}}{N_{jt}}$$

E.1.2 Bank choice

$$\frac{ds_{jt}}{df_{jt}} \approx \frac{1}{ns} \sum_i \frac{ds_{ijt}}{df_{jt}}$$

E.2 With respect to card usage fee f_{kt}

E.2.1 Card usage

$$\frac{\partial s^u_{jt}}{\partial f_{kt}} \approx \sum_i \left\{ s^u_{ijt} \left[\frac{\partial s_{ijt}}{\partial f_{kt}} \frac{1}{\sum_i s_{ijt}} - s_{ijt} \sum_i \frac{\partial s_{ijt}}{\partial f_{kt}} \frac{1}{(\sum_i s_{ijt})^2} \right] \right\}$$

where

$$\frac{\partial s_{ijt}}{\partial f_{kt}} = \frac{\partial b_{ikt} E[D_{ikt}]}{\partial f_{kt}} s_{ijt} s_{ikt} \tag{57}$$

and the derivative $\frac{\partial b_{ikt} E[D_{ikt}]}{\partial f_{kt}}$ given by equation (56).

E.3 With respect to member fee F_{jt}

E.3.1 Card usage

$$\frac{ds^u_{jt}}{dF_{jt}} \approx \sum_i s^u_{ijt} \left[\frac{ds_{ijt}}{dF_{jt}} \frac{1}{\sum_i s_{ijt}} - s_{ijt} \sum_i \frac{ds_{ijt}}{dF_{jt}} \frac{1}{(\sum_i s_{ijt})^2} \right]$$

where

$$\frac{ds_{ijt}}{dF_{jt}} = -\alpha_i s_{ijt}(1 - s_{ijt}).$$

Plugging in $\frac{ds_{ijt}}{dF_{jt}}$ an rearranging:

$$\frac{ds^u_{jt}}{dF_{jt}} \approx \sum_i \alpha_i s^u_{ijt} \left(\frac{s_{ijt}}{\sum_i s_{ijt}} \right)^2 \left(2 - s_{ijt} - \frac{1}{s_{ijt}} \right)$$

E.3.2 Bank choice

$$\frac{ds_{jt}}{dF_{jt}} \approx \frac{1}{ns} \sum_i -\alpha_i s_{ijt}(1 - s_{ijt})$$

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