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Incompatibility, Product Attributes and Consumer Welfare: Evidence from ATMs

Christopher R. Knittel and Victor Stango*

Abstract

Incompatibility in market with network effects reduces consumers' ability to "mix and match" components offered by different sellers, but can also spur changes in product attributes that might benefit consumers. In this paper, we estimate the effects of incompatibility on consumers in a classic hardware/software market: ATM cards and machines. We find that while ATM fees *ceteris paribus* reduce the network benefit from other banks' ATMs, a surge in ATM deployment accompanies the shift to surcharging. This is valuable to consumers and often completely offsets the harm from higher fees. The results suggest that policy discussions of incompatibility must consider not only its direct effect on consumers, but also its effect on product attributes.

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Stango: Tuck School of Business, Dartmouth College. *Email*: victor.stango@dartmouth.edu. Carrie Jankowski and Kaushik Murali provided excellent research assistance. We thank Andrew Bernard, Jeff Campbell, Astrid Dick, Ed Green, Tim Hannan, Tom Hubbard, Ariel Pakes, Robert Pindyck and Catherine Wolfram for helpful comments. Seminar participants at Berkeley (Haas), Dartmouth (Tuck), the Federal Reserve Banks of Chicago and New York, Penn State University, UCSD, the 2004 AEA Meetings and the 2004 NBER Summer Institute also provided constructive comments. The authors gratefully acknowledge the financial support of the NET Institute.

1 Introduction

The last two decades have witnessed a dramatic increase in the importance of markets with *network effects*.¹ In these markets, the effect of incompatibility between “platforms” sold by separate firms is a central policy concern, and one on which theory is ambiguous. To illustrate, one can easily imagine that incompatibility between competing video game consoles reduces welfare by preventing one platform’s console owners from using the other’s proprietary game software. However, incompatibility strengthens the incentives to develop such software—because outstanding software attracts customers from competing platforms. Ultimately, this might benefit consumers. It is this tension that we examine here: Incompatibility reduces consumers’ options for cross-platform matching, but may also lead platform owners to change their product attributes in ways that improve welfare.²

Our empirical setting is a classic “hardware/software” industry: Automated Teller Machines (ATMs) and ATM cards. In this market, network effects arise because consumers can use ATM cards and ATMs owned by different banks. However, banks impose fees for such “mix and match” transactions, introducing partial incompatibility between cards and competitors’ machines. To continue the analogy above, with zero ATM fees, consumers may freely match hardware (cards) and software (ATMs) offered by different platforms (banks). Fees reduce or eliminate this ability. Our data display both cross-sectional and time-series variation in this fee-based measure of incompatibility, providing a rare opportunity to observe its effects. We also observe changes in the sizes of banks’ ATM fleets. This allows us to estimate not only the direct effect of incompatibility on cross-platform matching, but also the second effect: shifts in product attributes, as represented by increased ATM deployment. The key empirical question that we examine is whether on balance the shift toward incompatibility leaves consumers better or worse off.

Our data are well-suited for such an analysis. We conduct our empirical work using ATM-related data for banks operating in different local markets throughout the United States. Our data cover the period 1994-1999, containing roughly ten thousand bank/county/year observations. Each observation contains information regarding the bank’s ATMs and ATM fees, as well as the number of competitors’ ATMs available to customers and their fees. It also contains information regarding deposit account (ATM card) prices and market shares, as well as characteristics associated with these accounts. Thus, we possess panel data on prices, quantities and characteristics for both components of the network good, as well as a measure of incompatibility. Our data also contain a

¹See Katz and Shapiro (1994) for a summary of the literature and its key points.

²We focus here on consumer welfare rather than social welfare. Massoud and Bernhardt (2002) and others argue that while consumers may benefit from the investment incentive we sketch here, it may be socially inefficient.

relatively discrete move toward incompatibility after 1996, when banks began imposing surcharges on foreign transactions made by non-customers on their ATMs.

The empirical approach involves estimating a structural model of consumer demand for deposit accounts (ATM cards) as a function of deposit account prices, ATM fees, ATM density and other bank characteristics. The model allows us to estimate consumers' willingness to pay for deposit accounts, and the influence of ATMs on willingness to pay. It also allows us to estimate the indirect network effect: the relationship between willingness to pay for an account and competitors' ATM fleet size. Finally, we estimate the relationship between competitors' ATM fees and willingness to pay for competitors' ATMs; this captures the effect of incompatibility.

The estimated parameters from this model provide the basis for our welfare analysis. The first component of the welfare effect is the partial equilibrium reduction in consumer welfare resulting from the shift toward incompatibility. Our results suggest that incompatibility *ceteris paribus* harms consumers during our sample. We also provide a fuller estimate that incorporates changes in ATM deployment—both for a given bank's own ATMs and its competitors' ATMs. ATM deployment increases with surcharging, providing benefits to customers that in some cases completely offset the reduction in welfare associated with incompatibility. Roughly stated, the net effects on welfare are more likely to be positive in urban areas, and more likely to be negative in rural areas. We also estimate split sample specifications that allow the demand parameters to vary by local market population density. We find that the network effects associated with ATMs and cards are much stronger in areas with high population density. This is consistent with the idea that in areas with high travel costs, ATM access is more valuable to consumers. Using the parameters from the split samples, we find that welfare changes in low density markets are negative, while welfare changes in high-density areas average roughly fourteen percent.

To our knowledge, ours is the first empirical study to examine changes in incompatibility and product attributes in a market characterized by indirect network effects.³ To date, most research has examined the value of compatibility across different products in markets with direct network effects.⁴ It also has focused on instances where compatibility between products remains fixed over time, relying on cross-sectional variation in compatibility for identification.⁵ While this other work

³An exception is Greenstein (1994), who finds that mainframe buyers prefer to upgrade to compatible systems, a result suggesting that compatibility between past and future hardware is important.

⁴Gandal (1994, 1995) and Brynjolfsson and Kemerer (1996) find that computer spreadsheets compatible with the Lotus system commanded higher prices during the early 1990s.

⁵The analyses in Gandal (1994, 1995) and Brynjolfsson and Kemerer (1996) do not separate within-firm from cross-sectional effects of compatibility. The datasets are panels, but too small to allow the examination of within-firm

is important, most policy discussions of incompatibility involve forcing compatibility within a given market. Our work is the first to examine not only the within-market (and within-firm) effects of a shift to incompatibility, but also the complementary shifts in product attributes induced by such a shift. Our work does relate to a developing literature establishing empirical relationships in markets with indirect network effects, although typically this work examines markets in which compatibility between different systems is fixed.⁶ It also complements existing literature examining ATM markets, although that literature does not focus on incompatibility *per se*.⁷

2 ATMs, ATM Cards and ATM Fees

ATMs allow bank customers to perform financial transactions electronically. ATMs initially served banks' desires to cut costs by automating tasks performed by bank tellers. While ATMs can in principle perform more complex transactions such as deposits or loan payments, the most common transaction is a cash withdrawal.⁸ Banks locate or *deploy* ATMs both "on-premise" at branches, and "off-premise" at other locations likely to generate significant transaction volume.⁹ Independent Service Operators (ISOs) also deploy ATMs, typically in lower-volume locations such as convenience variation.

⁶Gandal, Greenstein and Salant (1999) study the link between operating system values and software availability in the early days of the microcomputer market. They find evidence supporting the existence of complementary feedback between hardware and software availability. More recent work by Gandal, Kende and Rob (2002) seeks to establish a positive feedback link between adoption of Compact Disks (CDs) and CD players. Rysman (2000) provides evidence supporting the existence of complementary demand relationships in a two-sided platform market (yellow page directories). More recent work by Shankar and Bayus (2002), Nair, Chintagunta and Dube (2003) and Ohashi (2003) also applies structural econometric techniques to test for the existence of network effects.

⁷Hannan *et al.* (2003) examine surcharging although they do link surcharging to deposit account pricing. Prager (2001) tests whether small banks lost market share in states that allowed surcharges prior to 1996; this is implicitly a test of whether incompatibility favored banks with high-quality ATM fleets, although she does not pose the question in those terms. Hannan and McDowell (1990) find that markets in which large banks adopted ATMs became more concentrated during the 1980s, although they do not discuss their finding in terms of network economics. Saloner and Shepard (1995) examine the diffusion of ATM machines from 1972-1979 and find that adoption occurred earliest for firms with many branches and deposits, a result they interpret as consistent with the existence of indirect network effects in demand. Earlier work by Hannan and McDowell (1984a, 1984b) also examines the causes of ATM adoption but does not test for network effects.

⁸Dove Consulting (1999, 2002) finds that in both 1999 and 2002, roughly eighty percent of ATM transactions were cash withdrawals. Deposits and inquiries comprise roughly ten percent each.

⁹Monthly costs of ATMs average over \$1000 for high-end machines, and may be as low as \$500 for low-end machines offering fewer features and using cheaper telecommunications. Rental expenses for off-premise ATM deployment may add \$200/month to this figure.

stores, restaurants and bars.¹⁰

Banks grant consumers access to their ATMs by providing ATM cards with checking (demand deposit) accounts. The deposit account also carries other services, such as check-writing and direct deposit for paychecks. Banks are differentiated both horizontally through geography, and vertically through service quality. Survey evidence suggests that the most important account features in determining customer attraction and retention are service quality and ATM/branch location.¹¹ Customers also may value purchasing other financial services such as loans or brokerage services from their depository institution; the breadth of these offerings is therefore a source of both horizontal and vertical differentiation.

Customers pay both implicit and explicit prices on deposit accounts. The implicit price is the opportunity cost of holding cash in a non-interest bearing account, or earning an interest rate below the risk-free rate if the checking account pays interest. Explicit costs may include a monthly service charge, fees associated with transactions (such as check-writing), and penalty fees such as NSF (insufficient funds) fees. Banks often offer customers a menu of options, trading lower explicit fees or interest payments for higher minimum balances. The menus are usually determined at the bank level, and identical across all branches for that bank.¹² While total account prices for any one customer may vary in principle depending on their pricing plan and balances, available survey evidence suggests that these prices are similar for accounts with or without minimum balances, averaging roughly \$144 per year.¹³

Consumers typically pay no per-transaction fees for ATM transactions made at their own bank's machines. They can also make *foreign* transactions on other banks' ATMs, because during the 1980s most banks joined "shared networks" that allow consumers to use their card at any ATM owned by a bank in the network. These ATM networks, which are often joint ventures organized by member banks, provide switching services for each foreign transaction made on a member bank's ATM by another member bank's customer. The networks jointly establish a fixed subscription fee for each member bank in the network, a per-transaction switch fee paid by the cardholder's bank to the network, and a per-transaction interchange fee paid by the cardholder's bank to the ATM owner.¹⁴

¹⁰See Dove Consulting (1999, 2002) for more details.

¹¹See Stavins (1999) and Kiser (2003) for discussions of account characteristics valued by banking customers.

¹²Radecki (1998) provides evidence in favor of this point.

¹³See Stavins (1999) for details.

¹⁴Data from the *Card Industry Directory* show that network subscription fees vary substantially, with larger national networks charging higher fees (as much as \$25,000 for membership and \$500 monthly). Interchange fees range from \$0.30-\$0.60 per transaction during our sample, and switch fees range from \$0.02-\$0.12. Many networks apply some sort of volume discount to their pricing.

By the mid-1990s, shared networks had expanded to the point that an ATM card would function at nearly any ATM in the country.¹⁵

A foreign transaction may generate a *foreign fee* paid to the consumer's home bank, and a *surcharge* paid to the owner of the ATM. Foreign fees exist throughout our sample and remain roughly constant, while surcharges are a more recent phenomenon. Prior to 1996, the major ATM shared networks (PLUS and Cirrus) prohibited banks from imposing surcharges. The major shared networks ostensibly prohibited surcharging in an attempt to build consumer acceptance of foreign transactions. The prohibition on surcharging was challenged by both banks and state legislatures; banks claimed that surcharging would enable them to deploy ATMs in lower-volume locations, while states viewed the ban as a potentially illegal vertical restraint. Prior to 1996, sixteen states overrode the surcharge bans. Furthermore, antitrust actions regarding the surcharge ban were being considered by the Department of Justice. Facing this pressure, the leading networks eliminated the ban. From 1997-1999, most banks adopted surcharges, and they are currently nearly universal. Both foreign fees and surcharges are set at the bank level; it is rare for a bank to set different fees across machines or markets.¹⁶

Table 1 shows summary statistics regarding ATM fees, deployment and transaction volume during our sample period 1994-1999. The data illustrate that while foreign fees remain roughly constant throughout our sample period, surcharging becomes much more prevalent after its inception in 1996.¹⁷ Concurrent with the advent of surcharging is an increase in ATM deployment; the average annual growth rate is under fourteen percent from 1993-1996, and nearly eighteen percent after 1996. Transaction volume holds steady after the advent of surcharging, after growing rapidly prior to 1996. This leads to fewer transactions per ATM, a pattern consistent with the notion that the break-even number of transactions per ATM is much lower if foreign transactions generate surcharge revenue.¹⁸

¹⁵Currently it is most common for a bank to subscribe to one of the major national networks, and one or two regional networks (which have priority in switching transactions relative to the national networks). It is also quite common for banks to subscribe to the VISA or MasterCard networks, allowing their customers to use their ATM cards to perform signature-based "offline" debit transactions on those networks.

¹⁶Our data from the *Card Industry Directory* allow banks to list a range of fees. Fewer than ten percent do so. Additionally the *Bank Rate Monitor* web site, www.bankrate.com, lists ATM fees by geographical region for multi-region banks. There is little evidence from this source that banks charge different fees on ATMs in different locations.

¹⁷These data show that some banks imposed surcharges in 1996; these banks either operated in states that overrode the surcharge ban, or subscribed to smaller networks that did not adhere to the ban. Unfortunately, we do not possess data in our primary sample on surcharging prior to 1997.

¹⁸This difference is dramatic. A study by Dove Consulting estimates the monthly accounting costs of maintaining

2.1 The Network Economics of ATMs and ATM Cards

In the language of the literature on network economics, ATM cards and machines are a “hardware/software” system.¹⁹ Consumers purchase “hardware” in the form of an ATM card by choosing a bank and establishing an account. ATMs are “software” that allow consumers to assemble a composite good—a financial transaction that is usually a cash withdrawal. This “mix and match” construction of goods is a common feature of emerging technologies, and is analogous to that involved in consumers’ matching of computer hardware and software, operating systems and spreadsheets, different components of audio/visual systems, and a variety of other products.²⁰ In ATM markets, as in many of the aforementioned examples, firms produce both hardware and software, and offer their customers bundles containing both. Thus, a customer establishing an account receives both an ATM card and free access to that bank’s ATMs. Our focus in this paper is on estimating consumer welfare. We therefore are concerned primarily with the implications of network effects for consumers’ willingness to pay for components of the system—which in our case is the hardware/software bundle offered by banks. Our discussion takes firms’ strategic behavior regarding pricing, incompatibility and quality as given, and focuses on the effects of changes in these factors on consumers. This parallels our empirical approach, which uses variation in incompatibility to estimate changes in consumer welfare.

We would expect a consumer’s willingness to pay for an account and associated ATM services to depend on the characteristics of the account—service quality, for example, as well as any complementary services offered with the account. One (internalized) indirect network effect in the bundle is that willingness to pay should also depend on the bank’s own ATMs. Consumer incur travel costs to use ATMs; therefore, a greater number of local ATMs reduces travel costs and makes an account more attractive. It also means that if consumers value accounts based on which bank has the ATMs closest to “home,” more consumers will be closer to an ATM of that bank. The second indirect network effect on willingness to pay is that competitors’ ATMs also provide benefits, be-

an ATM at roughly \$1200. If interchange (\$0.40 per transaction) is the only source of ATM revenue, the break-even number of foreign transactions per month is 3000. If interchange plus surcharging yields revenue of \$1.90 per foreign transaction, the break-even monthly number of foreign transactions falls to 631.

¹⁹See Katz and Shapiro (1994) for a survey of this literature. Economides and Salop (1992) present a theoretical model of hardware/software competition using ATMs as an example.

²⁰There has been considerable theoretical work examining hardware/software markets. Chou and Shy (1990), Church and Gandal (1996), and Matutes and Regibeau (1988) consider cases where hardware and software are sold by integrated firms. Economides and Salop (1992) provide a comparison of market structures characterized by different forms of integration and ownership among component (hardware and software) producers. Matutes and Regibeau (1992) examine a case where firms produce both hardware and software, and may bundle them together.

cause ATMs operate on shared networks. While consumers may prefer to use an ATM operated by their own bank (even absent fees, they can perform a wider array of transactions on their own ATMs), they also should value occasional access to other banks' ATMs.

2.2 Incompatibility and its Effects

In hardware/software markets, the compatibility issue revolves around whether Firm A's hardware will function with Firm B's software, and vice versa. ATM fees create incompatibility by increasing the cost of access to other banks' ATMs. While surcharges do not render competitors' ATMs fully incompatible, they impose an incremental expense for foreign ATM use. In the language of network economics, this expense is most analogous to an "adaptor fee" paid by software users to achieve compatibility with potentially incompatible hardware.²¹

Generally speaking, there are three effects of incompatibility in such markets. The most general effect is that incompatibility reduces consumers' willingness to pay, *ceteris paribus*. The strength of this effect depends on the degree to which consumers want to mix and match hardware and software from different sellers. If demand for such transactions is zero, incompatibility leaves consumers unaffected, but if demand for mix and match transactions is high, incompatibility reduces aggregate willingness to pay. These effects may vary by firm; firms with high demand for mix and match transactions will experience a larger reduction in willingness to pay. In our data, this effect should weaken the relationship between willingness to pay for an ATM card (account) and the number of accessible competitors' ATMs.

A second effect of incompatibility operates through product attributes. With incompatibility, consumers' hardware and software purchases become more tightly linked. Thus, changes in software attributes will have a stronger effect on hardware purchases, increasing the marginal benefit of such investment.²² Within our context the argument would be that incompatibility increases firms' incentives to invest in their ATM fleets.²³ High surcharges, the argument goes, induce customers with high demand for foreign transactions to migrate from banks with small ATM fleets to banks

²¹See Farrell and Saloner (1992) for a model of adaptors in a hardware/software market.

²²But for the papers by Massoud and Bernhardt (2002a, 2002b), this notion has received little formal attention. Katz and Shapiro (1994) mention the possibility that incompatibility spurs investment, but only in passing. The classic papers on "mix and match" competition such as Matutes and Regibeau (1988) and Economides (1989) assume that product characteristics are fixed. Einhorn (1992) models the effect of quality differences across component producers, but assumes that such differences are exogenous.

²³These incentives are the primary focus of the theoretical models of ATM pricing and deployment in Massoud and Bernhardt (2002a, 2002b).

with large ATM fleets. This is analogous to arguments regarding incompatibility in the network literature; incompatibility can shift competitive advantage in one market (hardware) by tying consumers' purchases to another market (software). Anecdotally this appears to be the case; the data from Table 1 reveals that within our sample, the annual growth rate of ATMs increased from roughly fourteen percent to over eighteen percent after 1996.

A third effect of incompatibility is that it may change the intensity of competition. Here again theory is ambiguous; models of competition in mix and match markets find that incompatibility may either intensify or weaken price competition.²⁴ Despite this theoretical ambiguity, our intuition tells us that in ATM markets the advent of surcharging would probably weaken price competition.²⁵ Without ATM fees of any sort, ATM fleet size is not a source of horizontal or vertical product differentiation. As fees rise, the degree of differentiation also rises, which we would expect to weaken business-stealing opportunities. Our empirical work below should control for such shifts in competitive behavior, although we can not identify the size of their effects.

To summarize, a full analysis of the effects of incompatibility should estimate not only the reduction in utility stemming directly from incompatibility, but also any changes in product attributes and price competition associated with the shift toward incompatibility. From a theoretical perspective it is not clear which effect will dominate. Our approach below is to focus on the direct effects of incompatibility as it operates through ATM fees. We also estimate how the direct reduction in welfare from incompatibility is offset by changes in product attributes. While we do not estimate the effects of changes in price competition, we discuss its impact later in the paper.

3 Modeling

In order to measure the effects of incompatibility on consumer welfare, we estimate a structural demand system for deposit account services and ATM usage. This follows techniques developed by Berry, Levinsohn and Pakes (1995), building on Lancaster (1966). The essence of the empirical approach is to estimate the relationship between consumer utility and product characteristics; specific products are modeled as bundles of characteristics. Under specific assumptions regarding the functional form of preferences on observed and unobserved characteristics, there is a structural

²⁴The discussion in Katz and Shapiro (1994) mentions instances in which compatibility might intensify price competition. Matutes and Regibeau (1988), Economides (1989) and Einhorn (1992) all find that compatibility relaxes price competition. Katz and Shapiro (1986) find that in a dynamic setting, compatibility has different effects on competition at different points in the product life cycle.

²⁵We find evidence consistent with this view in Knittel and Stango (2004).

relationship between aggregate firm-level market shares and the parameters of consumers' indirect utility functions. This approach is more parsimonious than traditional demand system estimation, as it reduces the large matrix of own- and cross-price elasticities to a smaller matrix of coefficients associated with product characteristics.

3.1 Consumer Behavior

In our econometric framework, the fundamental consumer choice is the establishment of a demand deposit (checking) account relationship with a bank. Consumers choose from the set of banks within their county in order to maximize indirect utility.²⁶ Consumer i 's utility for bank j in county k in year t is a function of the price for a deposit account p_{jt} , bank j 's observable deposit account characteristics x_{jkt} in county k in year t , the access to ATMs N_{jkt} provided by obtaining an account, the bank's unobservable characteristics ξ_j , county level unobservable characteristics ξ_k , bank/county unobservable characteristics ξ_{jk} , unobservable year-specific characteristics ξ_t and a mean zero term ϵ_{ijkjt} capturing unobserved consumer heterogeneity.²⁷ This yields the following specification:

$$u_{ijkjt} = \alpha_i p_{jt} + x_{jkt} \beta_i + N_{jkt} + \xi_{jk} + \xi_t + \epsilon_{ijkjt} \quad (1)$$

While in practice the vector of marginal utility coefficients (α_i, β_i) varies by consumer, in this instance we restrict the coefficients to be constant across consumers. By omitting income from the utility function, we are assuming that there are negligible income effects when establishing a deposit account. Given the low share of consumer income devoted to purchasing checking account services, we feel this is reasonable. The assumption is also a function of our data, which do not lend themselves to such an analysis.²⁸

²⁶Using counties to approximate local markets is common in the banking literature. Some recent work (e.g., Radecki [1998]) argues that geographic banking markets have expanded. However, we feel that while this may be true for products such as loans, it is much less likely to be true for ATM-related services. In fact, we use the county as the market even in MSAs, rather than treating the MSA as the market. In practice this has no effect on our results.

²⁷While in principle there are separate bank effects ξ_j , county effects ξ_k and bank/county effects ξ_{jk} , in practice we nest them within ξ_{jk} .

²⁸Our data are measured at the bank/county/year level, but income data are only available at the state/year level. The BEA publishes county/year income figures, but these are interpolated between decennial Census figures rather than actually observed.

3.2 Deriving the Estimating Equation

As shown by Berry (1994), if ϵ_{ikjt} follows an extreme value distribution one can integrate the individual utilities to obtain an estimating equation that provides a structural relationship between the utility parameters and market shares for each firm. This yields the following equation:

$$\ln(s_{jkt}) = \alpha p_{jt} + x_{jkt}\beta + N_{jkt} + \xi_{jk} + \xi_t + \Delta\xi_{jkt} \quad (2)$$

This is a useful transformation, because while we do not observe individual consumer choices, we do possess bank/county/year observations on market share, prices and other explanatory variables of interest. Note that the consumer-specific heterogeneity has been “integrated out” here, and we are left with the bank/county/year specific term $\Delta\xi_{jkt}$ capturing unobserved quality.

While econometrically tractable, the specification of utility that leads to this estimating equation is quite restrictive.²⁹ A significant limitation is that a proportional increase in all bank prices will not reduce demand for banking services. A common way to guarantee that banks lose market share when prices rise involves choosing an “outside good” to which consumers can switch given an increase in prices by all banks. In our case, we not only observe deposits for banks in each county, but also observe deposits for credit unions; these institutions are imperfect substitutes for banks and are the product to which consumers might conceivably switch given higher bank prices.³⁰ We therefore treat banks as the “inside good” and credit unions as the outside good.

Another way of enriching the model is to assume that consumers make a two-stage decision, in which they first decide whether to establish an account at a credit union or at a bank. Given that choice, they make their second stage decision regarding which institution to establish an account. This allows for more intuitive substitution patterns, in which a consumer switching away from a bank is more likely to switch to another bank than to a credit union. In a manner similar to that outlined above, one can begin with a general specification in which consumers have heterogeneous preferences for remaining in each “nest.” These are also integrated out under specific assumptions regarding the form of the heterogeneity. As Berry (1994) shows, this leads to the following nested logit estimating equation:

$$\ln(s_{jkt}) - \ln(s_{okt}) = \alpha p_{jt} + x_{jkt}\beta + N_{jkt} + \sigma_t \ln(\bar{s}_{j|g}) + \xi_{jk} + \xi_t + \Delta\xi_{jkt} \quad (3)$$

²⁹See Nevo (2000) for a discussion of these issues, and some improvements to the model we use here.

³⁰To be more precise, we treat banks and thrift institutions as the inside good. We have also estimated the model treating banks as the inside good, and thrifts/credit unions as the outside good. This has little effect on the results.

The term s_{okt} is the market share of the outside good, while $\bar{s}_{j|g}$ is bank j 's share of the inside good. The term σ_t represents the correlation between consumer choices within each nest; higher values of σ_t reflect a higher likelihood that a consumer switching away from one bank will choose another bank rather than a credit union. Letting the term vary by year allows the substitutability between the inside and outside goods to change over time.

3.3 Measuring Market Share

We use data from the FDIC *Summary of Deposits* database to obtain the total deposits held by each bank in each county of operation during our sample period.³¹ Similar data from the National Credit Union Administration (NCUA) yield deposit data for credit unions, which we use to calculate the share of the outside good.³² In our sample, the share of deposits held by the inside good falls slightly over time as credit unions gain market share. Anecdotally, it also appears that the substitutability of credit unions and banks grows during our sample as well, because credit unions have expanded their service offerings to more closely match those of banks.

One issue associated with our dependent variable is that it is based on total deposits held by each bank. Total deposits include not only checking (deposit) account balances, but also savings and other time deposits such as money markets and CDs. A second issue is that while our model is a discrete choice model, we are proxying the number of accounts with the level of deposits. Thus, total deposit market share may measure checking deposit market share with error. In principle, this can present a problem in our non-linear framework, even if the measurement error is of a form that is innocuous in more standard linear regressions.³³ In practice, however, there is little evidence that this error is significant.³⁴

3.4 Deposit Account Prices

We take pricing data on deposit accounts from the FDIC Reports of Condition and Income, or Call Reports. These data are available at the card issuer (bank) level. The variable listed in the Call Reports shows annual income from fees associated with deposit accounts. The primary component

³¹The SOD also contains deposit data for thrifts. While we use thrift deposit data in calculating market shares, we can not include observations for thrifts in our sample because we do not possess prices or other data for them.

³²The mean outside good share is roughly twelve percent in our sample; the interquartile range is [0.01, 0.16].

³³See Berry (1994) for a discussion.

³⁴At the bank level, the correlation between total deposits and demand deposits is 0.98.

of such revenue is income from monthly service charges on transaction accounts.³⁵ It also includes foreign fee income paid by its customers stemming from the use of other issuers' ATMs, and a variety of other fees such as NSF fees for bounced checks and other penalty fees on accounts. To calculate a normalized price for each bank, we divide this value by the end-of-year dollar value of deposits held in transaction accounts.³⁶ This price measure therefore represents the average revenue per dollar (per year) of transaction account balances. While it undoubtedly averages over the many different fees and fee schedules offered by each bank, this price measure is highly correlated with annual price measures using finer data.³⁷

This measure omits the additional opportunity cost of holding deposits in checking. While this opportunity cost surely varies across customers, Radecki (1999) suggests using the federal funds rate as an approximation of forgone interest income for demand deposit balances. We therefore add the average annual fed funds rate to each bank's price.³⁸ While this does not affect any of our coefficient estimates because they rely on within-bank variation in prices over time, it does provide a useful benchmark for comparing our price measure to others. As a point of comparison, we find that our raw price measure averages roughly \$0.01 per dollar of transaction balances, while the cost of funds averages roughly \$0.05. The typical checking account has average balances of \$1600, implying an annual cost of \$96. This figure is in line with other estimates in the banking literature.

The discussion above should make clear that our price variable is subject to measurement error. However, if this measurement error is fairly constant over time it is not an issue because we use within-bank variation to estimate the model.³⁹ Additionally, our instrumental variable procedure

³⁵This variable also includes income on other types of deposit accounts that do not carry ATM card access, introducing measurement error. However, these other types of accounts (such as savings) typically have lower fees than checking accounts. We examine within-bank variation in these fees, meaning that our results below will only be biased if within-bank variation in other fees is correlated with our variables of interest (e.g., ATMs). Most importantly, we use an instrumental variable approach that controls for the measurement error in price, as well as the endogeneity of price.

³⁶We have also used an alternative measure that divides deposit fee income by the dollar value of deposits. This is the variable used by Dick (2002) in her study of consumer welfare in deposit markets. Our results using this measure are nearly identical to those shown below.

³⁷Stavins (1999) regresses the fee variable used in our price on actual fee data from surveys (such as minimum balance requirements, monthly fees etc.) and finds that the explanatory variables explain over eighty percent of the variation in fee income.

³⁸We would expect there to be considerable consumer-level heterogeneity in the opportunity cost of funds. Consumers carrying credit card balances, for example, would have high costs. This might affect the bank-level cost of funds if consumers are not uniformly allocated across banks. However, our instruments (in particular those measuring the riskiness of a bank's customer base) should capture at least some of this variation.

³⁹Large banks tend to pay lower interest than smaller banks. This may reflect quality differences or market power.

outlined below should account for measurement error that varies over time. Finally, in other work we estimate a series of hedonic relationships between account prices and characteristics using a wide variety of price measures (such as revenue per account rather than per dollar of balances), and also controlling for bank-level balances per account and other possible influences on measured prices.⁴⁰ There is little difference in the empirical results using these different measures.

3.5 Specifying the Benefits of ATMs

The access to ATMs associated with an account, N_{jkt} , will depend on bank j 's ATM deployment in the local market. It will also depend on the network effects conferred by other banks' ATMs, and the compatibility of those other ATMs. We model this access using the following specification:

$$N_{jkt} = b_1 \ln(\text{OwnATMs}_{jkt}) + [b_2 + b_3 E(sc_{-j,kt})] \ln(\text{CompetATMs}_{jkt}) \quad (4)$$

The first parameter, b_1 , measures the value of bank j 's ATMs in the local market.⁴¹ We measure the ATM variable in logs to capture the declining marginal value of ATMs; the incremental effect of an additional ATM falls with more ATMs in the market, growing negligible as the market becomes saturated.

The second term estimates the value of the indirect network effect associated with the presence of competitors' ATMs. This value is represented by the term $[b_2 + b_3 E(sc_{-j,kt})]$, where b_2 represents the value of a competitors' ATM with full compatibility (zero surcharges), and b_3 represents the reduction in value from competitors' ATMs caused by surcharges. This gives the following specification:

$$\ln(s_{jkt}) - \ln(s_{okt}) = \alpha p_{jt} + x_{jkt} \beta + b_1 \ln(\text{OwnATMs}_{jkt}) \quad (5)$$

If savings rate differences stem from market power and consumers face switching costs, we will slightly overstate the price difference between large and small banks using our fee income variable.

Another issue to consider the sorting of different customer types (e.g., those with high and low balances per account) across different banks. More importantly, it does not allow changes in such sorting after the advent of surcharges. While such a shift is certainly possible, we have found no evidence that it occurred; we have examined movements in customer base data such as balances per account following 1996, and found no significant changes.

⁴⁰See Knittel and Stango (2004) for details.

⁴¹One might imagine that a density measure such as $\ln(\text{ATMs per square mile})$ might be appropriate. Our definition is equivalent with fixed county effects and our log specification, because the square mileage of counties does not change over time.

$$\begin{aligned}
& + [b_2 + b_3 E(sc_{-j,kt})] \ln(CompetATMs_{jkt}) \\
& + \sigma_t \ln(\bar{s}_{j|g}) + \xi_{jk} + \xi_t + \Delta\xi_{jkt}
\end{aligned}$$

One methodological issue associated with this specification is that it includes the impact of foreign fees only in the price term p_{jt} . While in one sense foreign fees are a part of the consumer's expected costs associated with an account, it is also true that foreign fees create incompatibility. While we can not separate the share of p_{jt} driven by foreign fee revenue, we do estimate specifications that allow a bank's foreign fees f_{jt} to affect the value of competitors' ATMs:

$$\begin{aligned}
\ln(s_{jkt}) - \ln(s_{okt}) & = \alpha p_{jt} + x_{jkt}\beta + b_1 \ln(OwnATMs_{jkt}) \\
& + [b_2 + b_3 (f_{jt} + E(sc_{-j,kt}))] \ln(CompetATMs_{jkt}) \\
& + \sigma_t \ln(\bar{s}_{j|g}) + \xi_{jk} + \xi_t + \Delta\xi_{jkt}
\end{aligned} \tag{6}$$

Another issue is that while we only observe surcharges in 1997 and beyond, some banks did begin to surcharge prior to that point because they operated in a state that had overridden the ban. We do know which states overrode the ban, allowing us to estimate a specification using a simple dummy variable to measure the transition to surcharging:

$$\begin{aligned}
\ln(s_{jkt}) - \ln(s_{okt}) & = \alpha p_{jt} + x_{jkt}\beta + b_1 \ln(OwnATMs_{jkt}) \\
& + [b_2 + b_3 (f_{jt} + E(sc_{-j,kt})) + b_4 I(k \in S_t \ \& \ t < 1996)] \ln(CompetATMs_{jkt}) \\
& + \sigma_t \ln(\bar{s}_{j|g}) + \xi_{jk} + \xi_t + \Delta\xi_{jkt}
\end{aligned} \tag{7}$$

where S_t is the set of state that overrode the surcharge bank. Thus, b_4 represents the reduction in the indirect network effect associated with competitors' ATMs in the states that overrode the ban prior to 1996, while b_3 measures the effect of incompatibility after 1996. In the main results section below, we report estimates from equation (7). We also report results using the other measures of incompatibility in appendix Table A3; the results are qualitatively very similar, although the coefficient on incompatibility is estimated more precisely in our preferred specification.

3.6 ATM-Related Data and Measurement Issues

While we possess data on market shares and deposits for the population of banks, we only observe data on ATM fees and deployment for the 300 largest ATM card issuers. While these issuers collectively hold a large share of the total market (for cards or machines), we do not observe such data for smaller issuers. The primary effect of this limitation is to reduce our useable sample size,

as we only include in our estimating sample those observations for which we observe both ATM fees and ATM deployment.

Another issue with our ATM data is that while we observe each issuer’s total ATM deployment, we do not observe the allocation of that deployment across counties. This is not a problem for single-county issuers, which represent twenty-five percent of our observations. For the other issuers, we assume that banks allocate ATMs across counties in proportion to their branches (which we observe without error from the Summary of Deposits). That is, we use:

$$OwnATMs_{jkt}^* = \frac{Branch_{jkt}}{Branch_{jt}} OwnATMs_{jt} \quad (8)$$

This introduces error into our measure of $OwnATMs_{jkt}$. To the extent that the measurement error is constant for a particular bank/county over time, our fixed effects will control for it. However, it is possible that there is time-varying bank/county measurement error. As is well-known, measurement error in an independent variable leads to attenuation bias, bringing the absolute value of the estimated coefficients closer to zero.⁴² A number of methods for correcting attenuation bias exist.⁴³ Below we discuss our method and some robustness checks of that method.

Competitors’ ATMs also are measured with error, because we do not observe ATM deployment for every bank in each county.⁴⁴ We rely on the information we do have regarding competitors’ branches to estimate competitors’ ATMs, using a regression-based method. We have experimented with several estimation methods, all of which yield similar results, in part because the ATM deployment of smaller issuers is fairly easy to predict; almost all smaller issuers deploy roughly one ATM per branch, with deployment growing slightly over time.⁴⁵ In the results shown here, we use a regression-based imputation method that uses data from our observed issuers to fit ATM

⁴²This result pertains to the univariate case. In a multivariate setting, correlation among (mismeasured) X’s can lead measurement error bias to be toward or away from zero.

⁴³See Fuller (1987) for an exposition of the problem and comprehensive treatment of the literature up to that point. One line of research proposes techniques when the “reliability ratio” or some other independently available index of the degree of error is available; see Fuller (1987) for examples and solutions. In the absence of such information, Griliches and Hausman (1986) and Biorn (2002) propose instrumental variable techniques appropriate for use with panel data, although their techniques involve differencing which would substantially reduce our sample size. Lewbel (1997) and Dagenais and Dagenais (1997) suggests using higher moments of the observed variables as instruments; we discuss and apply this technique below.

⁴⁴On average, the banks for which we observe ATM-related data collectively hold forty-seven percent of deposits in the county. Their share of ATMs in that county is almost surely higher.

⁴⁵For more detail on differences between large and small issuers, see Knittel and Stango (2004).

deployment for other issuers in local markets.⁴⁶

We also face measurement error in constructing a measure of competitors' ATM fees. We use a regression-based method for imputing expected competitors' surcharges.⁴⁷ Again, we have experimented with alternative methods of estimating competitors' fees, with little effect on the results. The shift to surcharging is fairly discrete, meaning that small differences in a prediction of competitors' surcharges are swamped by the change occurring between 1996 and 1998. In fact, using a simple dummy variable indicating whether competitors can impose surcharges yields results very similar to those shown below.

We are left with three independent variables that may be measured with error, meaning that our estimating equation is:

$$\begin{aligned} \ln(s_{jkt}) - \ln(s_{okt}) &= \alpha p_{jt} + x_{jkt}\beta + b_1 \ln(\text{OwnATM}s_{jkt}^*) & (9) \\ &+ \left[b_2 + b_3 \left(f_{jt} + E\left(sc_{-j,kt}^* \right) \right) + b_4 I(k \in S_t \ \& \ t < 1996) \right] \ln(\text{CompetATM}s_{jkt}^*) \\ &+ \sigma_t \ln(\bar{s}_{j|g}) + \xi_{jk} + \xi_t + \Delta\xi_{jkt} \end{aligned}$$

We address the measurement error issue by implementing the procedure in Lewbel (1997). This involves using higher moments of the observable data (the x_{jkt} 's) as instruments for the variables that are measured with error.⁴⁸ In the results below, we present both estimates that use this EIV-IV (Error-in-Variables Instrumental Variable) correction and estimates that do not, and discuss

⁴⁶In order to estimate the number of ATMs deployed by other institutions, we estimate a within-sample regression of ATMs on branches, year dummies and year/branch interaction terms. To control for the fact that larger institutions have a greater ratio of ATMs to branches, we allow issuer size (in deposits) to affect branches per ATM. We also allow branches per ATM to vary based on whether the issuer is located in an MSA or non-MSA county. We then construct fitted values of ATMs for each institution for which we do not have ATM data. We have experimented with a number of alternative specifications of this model, with essentially no change in the results.

⁴⁷We first estimate the within-sample probability of surcharging and surcharge level (conditional on surcharging) based on issuer size, year effects, MSA dummies and interactions between these variables. We then predict the expected surcharge (probability of surcharging multiplied by expected surcharge) for each competing bank. The expected competitors' surcharge is an average of these and observed surcharges over all competitors in the local market, weighted by each competitors' share of branches in the local market.

⁴⁸These instruments will provide consistent estimates of the true parameters if the joint distribution of the variables measured with error is not multivariate normal—in particular, if the distribution is skewed. We report the results that use moments of branch density as instruments. Given that we use branch density to imput county-level ATM density, there may be some concern that branch density will be correlated with the measurement error. Omitting these instruments does not qualitatively change the results.

their differences. We also conduct some robustness checks using different imputation methods and split samples, which we discuss in the “Alternative Specifications” section below and present in the Appendices.

The specification above omits two variables. First, it omits growth in ATMs deployed by ISOs. Unfortunately we possess no regional data on deployment by these ATM owners. Aggregate data suggest, however, that between 1996 and 1999 the share of ATMs deployed by ISOs grew from nearly zero to roughly ten percent. This implies that our estimates of post-1996 ATM growth are too low; this becomes an issue in Section 5 when we estimate the relationship between surcharging and ATM deployment. We discuss the implications of this when we present the empirical results.

A second limitation is that our specification does not include data regarding the availability of point-of-sale (POS) terminals. These terminals allow consumers to use their debit (ATM) cards to make purchases at retail locations such as supermarkets. Their availability has countervailing influences in our specification. First, the availability of POS terminals would certainly increase consumers’ willingness to pay for debit cards. On the other hand, POS terminals are a substitute for ATMs because they offer consumers an alternative means of payment. The effects of omitting POS terminals would depend on the correlation between the within-firm (log) change in POS availability and our variables of interest.

While we do not possess data on POS availability, we do observe POS transactions per card for our set of issuers. In unreported results, we have estimated models that include the level or log of POS transactions per card, as well as interaction terms between POS usage and the ATM-related variables. The results are not statistically significant. Moreover, including the POS variables does not affect the sign or significance of the ATM-related variables.

3.6.1 Endogeneity

The unobserved portion of quality that remains in the error term, $\Delta\xi_{jkt}$, is likely to be correlated with the price variable p_{jt} and the within-nest market share $\bar{s}_{j|g}$. Increases in unobserved quality will likely be correlated with both increases in price and within group share. We account for this following Berry (1994) and Berry, Levinsohn and Pakes (1995) by using costs and competitors’ characteristics as instruments.⁴⁹

⁴⁹Our cost measure is the bank’s average loan loss rate over the previous year. These loan losses affect banks’ net loan loss margins, which in turn affect equilibrium deposit account prices because banks use deposit account funds as the source of loans. Thus, exogenous variation in loan losses is plausibly correlated with deposit account prices, but uncorrelated with unobserved deposit account quality. The competitors’ characteristics include offerings

3.7 Variables and Descriptive Statistics

Table 2 lists yearly trends for the primary variables used in our analysis. In addition to the variables discussed above, we also define a set of bank-level variables capturing other characteristics associated with deposit accounts, for inclusion in the x_{jkt} vector. These variables follow closely the set used in other structural demand studies in banking.⁵⁰ We use county-level branches to measure convenience of access to non-ATM related services. We use employees per branch and salaries per employee to capture service quality. We measure the number of counties in which a bank operates, in order to allow willingness to pay to depend on the geographic breadth of a bank's operations. The average number of counties that a bank has branches in increases dramatically over the sample. This is the result of the Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994 that relaxed interstate branching restrictions. Finally, we define two dummy variables indicating whether the bank offers complementary services: money market accounts, and brokerage services. We would expect that increases in any of these variables would increase consumers' willingness to pay for accounts.

While we do not present the results here, in related work we examine our summary data in more detail in order to highlight the variation in our data that drives identification.⁵¹ In that work we observe two general trends. First, much of the within-firm increases in ATM density (and competitors' ATMs) appear to be accompanied by increased prices on deposit accounts. This pattern is in fact suggested by the data in Table 2 as well. Furthermore, we observe that the greatest changes in behavior occur for (a) large rather than small banks, and (b) urban rather than rural banks. It appears that the post-1996 increase in ATM deployment and any associated increase in deposit prices are concentrated primarily among large urban banks. In fact, among small urban banks ATM deployment stays essentially flat, while deposit prices actually fall. There is relatively minor variation in foreign fees or competitors' surcharges across these categories, although larger banks are more likely to impose surcharges themselves (thereby increasing competitors' surcharges for all other banks in the market). Interestingly, during all of these changes within-firm market shares are relatively stable, with the exception of small urban banks, who appear to lose some ground relative to large urban banks.⁵²

of brokerage services and money market accounts, which will vary by bank/county/year. This implicitly assumes that competitors' characteristics are exogenous from any one bank's perspective.

⁵⁰Dick (2002) is the first work to employ many of these variables.

⁵¹See Knittel and Stango (2004) for details.

⁵²Average market share falls in Table II above, but primarily due to sample composition.

4 Results

Table 3 reports the results from three specifications estimating equation (7).⁵³ The first specification uses OLS and ignores the endogeneity of prices and within-nest market share. The second specification instruments for prices and within-nest market share. The third specification implements the Error-in-Variables Instrumental Variable (EIV-IV) specification.

Patterns across the specifications seem sensible. The price coefficient grows more negative when we move to the IV specifications. The coefficients on the variables measured with error change significantly moving from the IV to EIV-IV specifications, and for the most part in an intuitive way. We expect that the competitors' ATMs and competitors' surcharges variables are measured with relatively more error than own ATMs; indeed, these coefficients change the most, and the EIV-IV estimates are farther away from zero.

Most of the coefficients on the x_{jkt} follow an intuitive pattern. Utility for deposit accounts increases with the number of branches, employees per branch, salary per employee and number of counties in which a bank operates. The dummy variables indicating complementary service offerings are not statistically significant, although in most specifications the coefficients are of the expected signs.

The coefficient associated with price represents the marginal utility of income, and allows us to interpret the other coefficients.⁵⁴ It also allows us to calculate the firm-level price elasticity of demand; we show summary data regarding these elasticity estimates in Table A4. The estimates are generally quite low, lying near one for most banks. One possible explanation for this is the significant anecdotal evidence that banks use checking account prices as loss leaders, in order to engage in cross-marketing for loan and other financial service products.

In order to clarify the economic interpretation of our results regarding the strength of network effects, we discuss them here in terms of price changes that would leave consumers indifferent to a given change in ATMs or incompatibility. Within this context we find that the indirect network effect between a bank's own ATM density and willingness to pay is strong; in exchange for a fifty

⁵³These results are nearly identical to those from the specifications in equations 5 and 6. This is not surprising; most of the within-firm variation in $f_{jt} + E(sc_{-j,kt})$ stems from variation in $E(sc_{-j,kt})$, as firms do not change their foreign fees very much. Similarly, most of the variation in $E(sc_{-j,kt})$ is fairly discrete and occurs in 1997 as firms initially adopt surcharging.

⁵⁴Because our price variable is measured as dollars per dollar deposited, measuring the marginal utility of income requires an assumption regarding account balances. We use the average account balance during our data because we do not have data regarding the distribution of deposits.

percent increase in own ATMs, the average consumer is willing to pay deposit account prices that are roughly seven percent higher. The effect of competitors' ATMs (absent fees) is also economically significant; for a similar fifty percent increase in competitors' ATMs the mean consumer would pay deposit fees nearly thirteen percent higher.⁵⁵

We also find significant effects of incompatibility. As the costs associated with using foreign ATMs increase, the value associated with competitors' ATMs falls. At the typical foreign cost of \$3.00, a proportional increase in competitors' ATMs is worth three-quarters as much as when these costs are zero. At a combined (foreign plus surcharge) cost of twelve dollars, the typical customer derives no value at all from competitors' ATMs—meaning that this level of incompatibility eliminates the indirect network effect.

5 Surcharging and Consumer Welfare

The parameter estimates from the structural model allow us to estimate the welfare effects of incompatibility. One component of the welfare change is the reduced value of competitors' ATMs as they become less compatible with customers' ATM cards. The other is the shift in product attributes following 1996—in particular, any increase in ATM deployment associated with the shift to incompatibility. Attempting to quantify the net effect of these changes requires not only the parameter estimates from the structural model, but an estimate of how ATM deployment changed after 1996. Given that ATM deployment was growing even before 1996, we estimate the shift in the growth rate after 1996 in order to avoid attributing all post-1996 deployment to surcharging. For each ATM related variable $\left[\ln(\text{OwnATMs}_{jkt}^*), \ln(\text{CompetATMs}_{jkt}^*), E(sc_{-j,kt}^*), \ln(\text{CompetATMs}_{jkt}^*), E(sc_{-j,kt}^*) \right]$ we estimate:

$$y_{jkt} = \alpha_0 + \alpha_1 t + \alpha_2 I(yr = 97) + \alpha_3 I(yr = 98) + \alpha_4 I(yr = 99) + \varepsilon_{jkt} \quad (10)$$

The parameter α_1 is the pre-1997 annual percentage change in the variable of interest, while α_2 , α_3 and α_4 are the cumulative changes in this growth for 1997, 1998 and 1999. Given our log-linear specification, these are conservative estimates; they assume that our variables of interest are

⁵⁵It may seem odd that an equal percentage increase in competitors' ATMs would be worth more than in own ATMs—but the base level of competitors' ATMs is much higher, meaning that it is a significantly larger increase in the total *number* of ATMs. Given the parameter estimates, consumers are always willing to pay more for an additional own rather than competitors' machine.

growing exponentially prior to 1997, and estimate shifts beyond such exponential growth.⁵⁶ We estimate three variations of equation (10). The first is a fixed effect regression at the bank/county level. Table 4 reports these results. For $OwnATMs_{jkt}^*$, the increase in the detrended increase in ATM deployment is 7 percent in 1999; for $CompetATMs_{jkt}^*$ the increase is 12 percent. The level of $E\left(sc_{-j,kt}^*\right) \ln(CompetATMs_{jkt}^*)$ increases by 4.6.

In the second specification, we allow growth rates to vary by state by estimating equation (10) for each state in our sample, pooling the bank/county observations. While this adds noise to our detrended growth rates, it allows for state level variation in the growth rates. Finally, we estimate equation (10) at the county level. The means of the state- and county-level estimates are similar to the aggregate measure reported in Table 4.

In Table 5, we use the parameters from Table 3 and our estimates of the increase in ATM deployment to calculate the change in consumer welfare over the period 1994-1999. Because we have estimates of the marginal utility associated with both ATMs and incompatibility, we can use these parameters and estimates of changes in the ATM/incompatibility variables to calculate utility changes for the typical consumer.⁵⁷ We provide both the partial effects of incompatibility holding ATM deployment constant, and fuller estimates incorporating the welfare gains from increased deployment. We present aggregate, state-level and within-county estimates. The aggregate estimates use the parameters from Table 5, and fix the changes in ATM-related variables at their sample mean values. The within-state and within-county estimates use the individual state- or county-level parameters, which we do not show to save space. We present both dollar value and percentage figures. The dollar value numbers can be used to calculate actual dollar costs to consumers from incompatibility. Recall that the typical consumer holds \$1600 in transaction balances over the year. Thus, finding that incompatibility reduced welfare by \$0.0051 implies an annual cost of \$8.16—or, roughly the cost of four foreign ATM transactions per year. On balance, the partial effects amount to a reduction in consumer welfare equivalent to an increase in deposit fees of roughly nine percent (or nine dollars per customer per year). Greater ATM deployment during our sample period increases consumer welfare. However, an unweighted average across our observation still shows the a reduction in consumer welfare equivalent to a 4-6% increase in deposit fees.

To provide some evidence on cross-market differences, Figure 1 shows a kernel density estimate of the percentage change in welfare from 1994 to 1999 for all counties in our sample. using the county specific estimates of ATM growth rates. The figure shows both the partial and full estimates.

⁵⁶We have also estimated linear and linear-log versions of this equation. These yield larger estimates of post-1996 increases in ATM deployment, and therefore more positive welfare estimates than those we report below.

⁵⁷Again, we use the average deposit account balance for these calculations.

The full estimates vary widely because we estimate significant variations across counties in the post-1996 shift in ATM deployment, and are positive for a substantial share of counties. Some of this heterogeneity may simply reflect noise in our estimates of county level changes. Nonetheless, it seems clear that there are some counties in which ATM deployment expanded extremely rapidly, and perhaps rapidly enough that the gains from increased deployment may have offset the effects of incompatibility. Many of these areas are urban markets; the mean post-1996 percentage shift in ATM deployment is close to zero in non-MSA counties, and nearly thirty percent in MSA counties. Figure 2 plots our estimated county-level welfare changes against the natural logarithm of county population density. The figure also includes a non-parametric Lowess smoothed line. There appears to be a significant positive relationship between the two and the non-parametric line is positive for population density levels above 400. A simple linear regression confirms this, yielding the following estimated relationship:

$$UtilChgPercent_k = -0.329 + 0.056 \ln(PopDens_k) \quad (11)$$

(0.028) (0.005)

While this estimate is admittedly rough, it predicts negative welfare effects for any county with population density below 356 persons per square mile—a figure typical of such medium-sized metropolitan areas as Kalamazoo county (Michigan) and Palm Beach county (Florida). Of the roughly nine hundred counties in our sample, over six hundred fall below this level. Another way of interpreting the results is that in a sparsely populated area such as Des Moines county (Iowa) with a population density of roughly 100 people per square mile, the model implies a welfare change of negative seven percent—while in a densely populated area such as Montgomery county (Maryland) with 1500 people per square mile, the model implies a welfare change of positive seven percent.

The above results regarding population density depend solely on differences in ATM deployment across markets, but it is also possible that demand parameters vary across markets. In particular, it seems likely that areas with high population density have higher travel costs. This might increase consumers’ willingness to pay for ATM services, since using ATMs involves traveling to them. To analyze the effects of travel costs further, we estimate equation (7) separately for counties above and below the median population density level. Lower travel costs should reduce the importance of ATM density as well as reduce the surcharge level for which competitor’s ATMs are no longer valued. The results for the ATM variables are reported in Table 6. In low population density markets, the value placed on ATMs is much lower and not statistically significant, while the “break

even” foreign cost falls to under three dollars. In contrast, high density markets place a greater weight on ATMs and competitors’ ATMs are valued even with very high foreign costs.⁵⁸

Table 7 repeats the welfare calculation using these parameters, while Figure 3 plots these welfare changes versus the log of population density for the base and split-sample models; the results are striking. Consumers in high travel cost counties experience substantially higher welfare after 1996, while the net effect remains negative for consumers in low travel cost counties. Figure 4 plots a Lowess smoothed line through the welfare scatterplot (note the change in scale). Comparing this to Figure 2 suggests that the welfare effect of surcharging becomes positive at a lower population density and has a steeper slope than implied by the base model.⁵⁹ While we repeat the caveat that these calculations ignore any shifts in the intensity of price competition following surcharging, these results do suggest that surcharging may have a positive effect on consumer welfare, especially if we focus on a population weighted average of consumer welfare.

6 Alternative Specifications

Tables A1-A3 report the results of the robustness checks we mention earlier in the paper. Table A1 compares EIV/non-EIV results from counties in which we observe relatively complete ATM data to those in which we observe less complete data.⁶⁰ Presumably, the measurement error (particularly in competitors’ ATMs) is greater in the latter counties. If true, this would imply a greater relative impact of the EIV correction. We find evidence in favor of this: in counties with relatively complete data EIV results are fairly similar to non-EIV results, while in counties with incomplete data this is not true. This suggests that our EIV-IV approach is correcting at least some of the bias.

We next estimate the model using three different imputation methods for the competitors’ ATMs. These results are described and reported in Table A2. For the most part, the results are robust to these alternative imputation methods. While the coefficient associated with competitors’ ATMs increases substantially in the last three models, this is because these models predict lower

⁵⁸These results are consistent with Knittel and Stango (2004), which suggests the bulk of the reduced form correlation between prices and ATM density is driven by observations from high density markets.

⁵⁹The linear relationship is: $UtilChgPercent_k = -0.435 + 0.081 \ln(PopDens_k)$.

⁶⁰One could also use the completeness of the data—for example, the fraction of banks in the local market for which we observe data—analogously to a “reliability ratio,” which can be used in corrections for attenuation bias. However, such corrections maintain the assumption that the actual measurement error is correlated with this share (which we expect but can not confirm), while the Lewbel (1997) procedure makes no assumptions regarding which observations display the greatest error.

levels of competitors’ ATMs, implying different percentage changes. The welfare changes resulting from post-1996 changes in ATM deployment and incompatibility are nearly identical in each case.

We also test the robustness of our results to the incompatibility measure, presenting these results in Table A3. While the standard errors are larger when using these alternative measures, the general pattern of the coefficients is unchanged.

7 Conclusions

In this paper, we estimate the importance of network effects and incompatibility in a classic “hardware/software” industry: Automated Teller Machines (ATMs) and ATM cards. Our empirical setting represents a rare opportunity to measure a relatively discrete change in incompatibility between cards and ATMs. We estimate a structural model of consumer demand for deposit accounts (ATM cards), allowing demand to depend not only on prices and characteristics directly associated with the account, but also on the ATM services provided indirectly with the account.

We find that ATM-related services play an important role in consumer behavior regarding deposit accounts. A bank’s own ATMs significantly affect the demand for its deposit account services. We also find a strong indirect network effect; consumers’ willingness to pay for deposit accounts is affected as well by the availability of competitors’ ATMs in the local market. This suggests that other research examining ATM fees should consider the interplay between ATM fees, ATM deployment and the demand for complementary deposit account services.

Our particular focus is the extent to which the direct welfare losses from incompatibility are offset by changes in product attributes. Surcharging significantly reduces the indirect network effect associated with competitor ATMs. In some markets, however, increased deployment offsets this loss. In general, the largest markets—which also have higher population density—experience increased welfare. This result is consistent with our demand estimates, which show that consumers value ATMs more highly in dense areas; it therefore seems sensible that we would observe the greatest increase in deployment in those area. It is possible that this result would be even stronger if we considered the impact of (unobserved) ATM deployment by ISOs, who typically concentrate their ATMs in metropolitan areas.⁶¹

⁶¹Dove Consulting (1999) estimates that ISOs had deployed 20,000 ATMs by 1999—roughly ten percent of the total deployed by banks. If all of this deployment could be attributed to incompatibility, and much was concentrated in areas of high population density, our estimates of welfare gains in urban areas might be significantly higher.

This result has important implications for the policy debate in ATM markets, and also furthers our understanding of the relationship between incompatibility and consumer welfare more generally. To reprise the analogy from our introduction, it suggests that the competition between incompatible platforms may benefit rather than harm consumers. Consumers can not mix and match hardware and software in such cases, which is surely harmful. However, this arrangement may increase platform owners' incentives to vertically integrate and invest in developing high-quality software.

Some open questions do remain. The social optimality of incompatible competition is something we do not explore. It is possible, for example, that the shifts in product attributes associated with incompatibility are inefficient even though they benefit consumers. Another open issue is the relationship between incompatibility and the intensity of price competition, an issue we do not explore in this paper but which may be important.

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A Appendix

A.1 Tables

Table 1: ATM Deployment, Fees and Usage 1994-1999

Sources: Fee data from the Federal Reserve Board's Annual Report to the Congress on Retail Fees and Services of Depository Institutions, various years. Other data from Faulkner and Gray's Card Industry Directory, various years. Figures for total ATM deployment include ATMs deployed by banks and ISOs.

Variable:	1994	1995	1996	1997	1998	1999
ATM Fees:						
Percent banks charging foreign fee:	78.4	85.3	79.8	67.0	74.5	72.3
Average foreign fee:	0.95	1.03	1.10	1.06	1.10	1.17
Percent banks charging surcharge:	—	—	44.8	60.1	77.9	82.9
Average surcharge:	—	—	1.19	1.14	1.20	1.26
ATMs (1000s):	109	123	139	165	187	227
ATM Cards (millions):	185	190	194	200	206	217
Annual ATM Transactions:	705	807	890	915	930	907
per card	45.7	51.0	55.1	54.9	54.2	50.2
per ATM (1000s)	77.5	79.0	76.8	66.5	60.0	48.0

Table 2: Yearly Means

Variable:	1994	1995	1996	1997	1998	1999
Deposit Share	0.147	0.142	0.139	0.137	0.136	0.121
ATMs	11.1	11.1	11.1	13.9	16.3	16.7
Competitors' ATMs	128.1	108.8	106.2	122.5	150.7	179.5
Account Fees (\$ per dollar of deposits/year):						
Excluding Opp. Cost of Funds	0.006	0.005	0.008	0.010	0.011	0.013
Including Opp. Cost of Funds	0.048	0.062	0.058	0.060	0.060	0.057
Foreign Fee (\$)	1.34	1.42	1.52	1.48	1.56	1.54
Competitors' Surcharges (\$)	0	0	0	0.81	1.01	1.25
Branches	8.7	8.5	8.9	8.7	8.7	8.5
Employees/Branch	23.4	22.1	21.4	21.4	22.9	21.4
Salary/Employee (\$1000)	17.1	18.1	20.0	20.2	21.1	22.6
Number of Counties	16	17	23	43	66	79
Share with MM Accounts	0.997	0.996	0.997	0.999	0.999	1.000
Share with Brokerage Svcs.	0.729	0.737	0.767	0.842	0.881	0.894

Observations are at the bank/county/year level. Number of observations is 9348.

Table 3: Nested Logit Results – Using variation in $f + E(sc_{-j,kt})$

Variable:	OLS	IV	EIV-IV
<i>Price</i>	-1.42 (1.08)	-13.00*** (4.84)	-11.63*** (4.83)
$\ln(ATMs)_j$	0.044*** (0.013)	0.140*** (0.020)	0.098*** (0.026)
$\ln(ATMs)_{-j}$	0.110*** (0.014)	0.092*** (0.026)	0.174*** (0.033)
$\ln(ATMs)_{-j} \times (f + E(sc_{-j,kt}))$	-0.011*** (0.004)	-0.010** (0.005)	-0.014*** (0.005)
$\ln(ATMs)_{-j} \times I(k \in S_t \text{ \& } t < 1996)$	-0.008 (0.020)	-0.009 (0.030)	-0.016 (0.022)
<i>Branches</i>	0.010*** (0.002)	0.022*** (0.003)	0.014*** (0.003)
<i>Employees/Branch</i>	0.0004 (0.0003)	0.0011** (0.0006)	0.0005* (0.000)
<i>Salary/Employee(\$1000)</i>	0.002 (0.002)	0.004* (0.002)	0.003* (0.002)
$\ln(\text{Number of counties})$	0.017*** (0.016)	0.074*** (0.020)	0.045** (0.018)
<i>Offer MM Accounts?</i>	0.121 (0.179)	0.094 (0.197)	0.119 (0.183)
<i>Offer Brokerage Svcs.?</i>	0.000 (0.021)	-0.013 (0.023)	-0.004 (0.022)
σ	0.832*** (0.015)	0.412*** (0.067)	0.662*** (0.053)
$\sigma \times I(\text{year} = 1995)$	-0.004 (0.009)	-0.030 (0.019)	-0.018 (0.017)
$\sigma \times I(\text{year} = 1996)$	-0.025*** (0.009)	-0.065*** (0.020)	-0.056*** (0.018)
$\sigma \times I(\text{year} = 1997)$	-0.018* (0.010)	-0.057*** (0.021)	-0.049** (0.020)
$\sigma \times I(\text{year} = 1998)$	-0.035*** (0.011)	-0.078*** (0.024)	-0.060*** (0.022)
$\sigma \times I(\text{year} = 1999)$	-0.060*** (0.013)	-0.118*** (0.028)	-0.090*** (0.025)
Instruments:			
Price and within share?	No	Yes	Yes
Measurement Error?	No	No	Yes
*** — significant at .01 or better			
** — significant at .05 or better			
* — significant at .10 or better			

Notes: N=9348. Standard Errors are in parentheses. All specifications include bank/county and year fixed effects.

Table 4: Aggregate Post-1996 Shifts in ATM-Related Variables

Variable:	Dependent Variable:			
	$\ln(ATMs)_j$	$\ln(ATMs)_{-j}$	$(f_{jt} + E(sc_{-j,kt}))$	$\ln(ATMs)_{-j} \times (f_{jt} + E(sc_{-j,kt}))$
t	0.101*** (0.006)	0.081*** (0.005)	0.086*** (0.004)	0.393*** (0.023)
$I(\text{year} = 1997)$	0.072*** (0.016)	0.077*** (0.011)	0.704*** (0.011)	2.854*** (0.058)
$I(\text{year} = 1998)$	0.045** (0.022)	0.098*** (0.016)	0.908*** (0.015)	3.776*** (0.080)
$I(\text{year} = 1999)$	0.032*** (0.014)	0.116*** (0.020)	1.024*** (0.019)	4.525*** (0.103)

Standard errors in parentheses. Bank/County fixed effects also included.

Table 5: Estimated Welfare Changes, 1994-1999

This table reports means and standard deviations of estimated welfare changes from surcharges. The first three calculations hold ATMs constant, while the final three account for the increased growth of ATMs. We use three methods for estimating the growth rates in the ATM-related variables. “Within-County Changes” estimates a single regression with county fixed effects. “State-Level Changes” estimates a separate regression for each state in our sample. Finally, “County-Level Changes” estimates a separate regression for each county in our sample. Calculations use sample average 1994-1999 shifts in ATM-related variables (see Table IV). Price units are dollars per year, per dollar of transaction deposit balances. Percent figures divide price unit changes by (bank-level) prices.

	Metric:	
	Price Units (\$)	Percent
Surcharging Only:		
Within-County Changes	-0.0051 (0.0017)	-9.01% (3.44)
State-Level Changes	-0.0053 (0.0037)	-9.54% (6.86)
County-Level Changes:	-0.0049 (0.0042)	-8.74% (7.85)
Surcharging and ATM Deployment:		
Within-County Changes	-0.0034 (0.0017)	-6.05% (3.26)
State-Level Changes	-0.0020 (0.0272)	-3.77% (48.50)
County-Level Changes	-0.0026 (0.0131)	-4.59% (23.82)

Table 6: High and Low Travel Cost Markets

Low travel cost markets are defined as having a population density below the median, while high travel cost markets are defined as having a population density above the median.

Variable	Low Travel Costs	High Travel Costs
$\ln(ATMs)_j$	0.025 (0.048)	0.134*** (0.026)
$\ln(ATMs)_{-j}$	0.077 (0.060)	0.269*** (0.034)
$\ln(ATMs)_{-j} \times (f_{jt} + E(sc_{-j,kt}))$	-0.026** (0.012)	-0.010** (0.005)

Standard Errors are in parentheses.

Bank/County and year fixed effects are also included.

*** denotes significance at the .01 level,

** significance at the .05 level, and

* denotes significance at the .10 level.

Table 7: Estimated Welfare Changes for Split Sample Model, 1994-1999

This table reports means and standard deviations of estimated welfare changes from surcharges for Low and High Travel Cost counties. We focus on the “County-Level Changes” in ATMs to be more comparable to Figures 3 and 4.

	Low Travel Costs		High Travel Costs	
	Price Units (\$)	Percent	Price Units (\$)	Percent
Surcharging Only:				
County-Level Changes:	-0.0092 (0.0086)	-16.15% (16.04)	-0.0052 (0.0042)	-9.41% (7.65)
Surcharging and ATM Deployment:				
County-Level Changes	-0.0104 (0.0097)	-18.23% (18.13)	0.0808 (0.0285)	14.47% (52.00)

Table A1: Nested Logit Results—Observability and EIV-IV Results

Variable	Card ID Share>50%		Card ID Share<50%		diff-in-diff
	No EIV	EIV	No EIV	EIV	
$\ln(ATMs)_j$	0.172 (0.164)	0.071** (0.036)	-0.074 (0.183)	0.111*** (0.034)	-0.084
$\ln(ATMs)_{-j}$	0.096 (0.101)	0.131*** (0.051)	0.298** (0.118)	0.144*** (0.042)	-0.119
$\ln(ATMs)_{-j} \times (f_{jt} + E(sc_{-j,kt}))$	-0.025 (0.025)	-0.010 (0.007)	-0.111*** (0.038)	-0.021*** (0.008)	-0.075
Observations	3778		5360		

Standard Errors are in parentheses. Bank/County and year fixed effects are also included.
*** denotes significance at the .01 level, ** significance at the .05 level, and
* denotes significance at the .10 level.

Table A2: Alternative Imputation Methods

Model 2 measures issuer size using categorical variables rather than the logarithm of deposits. Model 3 imputes one ATM per branch for those which lack data. Model 4 sets ATMs per branch for these banks equal to the median for observed banks within the same deposit level quartile. Model 5 sets ATMs per branch equal to the median for observed banks within the same deposit level quartile for MSAs and non-MSAs.

Variable	Base	Model 2	Model 3	Model 4	Model 5
$\ln(ATMs)_j$	0.098*** (0.026)	0.105*** (0.026)	0.091*** (0.026)	0.059 (0.059)	0.043 (0.056)
$\ln(ATMs)_{-j}$	0.174*** (0.033)	0.115*** (0.025)	0.179*** (0.032)	0.416*** (0.042)	0.420*** (0.042)
$\ln(ATMs)_{-j} \times (f_{jt} + E(sc_{-j,kt}))$	-0.014*** (0.005)	-0.014*** (0.005)	-0.016*** (0.005)	-0.021*** (0.005)	-0.021*** (0.005)

Standard Errors are in parentheses.

*** denotes significance at the .01 level, ** significance at the .05 level, and

* denotes significance at the .10 level.

Table A3: Alternative Measures of Incompatibility

Model 2 uses expected surcharges for the incompatibility measure, while Model 3 uses a post-1996 indicator variable.

Variable	Base	Model 2	Model 3
$\ln(ATMs)_j$	0.098*** (0.026)	0.126*** (0.028)	0.131*** (0.026)
$\ln(ATMs)_{-j}$	0.174*** (0.033)	0.115*** (0.036)	0.145*** (0.034)
$\ln(ATMs)_{-j} \times Incomp$	-0.014**** (0.005)	-0.044 (0.035)	-0.033 (0.029)

Standard Errors are in parentheses.

*** denotes significance at the .01 level,

** significance at the .05 level, and

* denotes significance at the .10 level.

Table A4: Estimated Price Elasticities

	Mean	Median	25th Percentile	75th Percentile
Own Price Elasticity	1.214	1.195	1.023	1.372

A.2 Figures

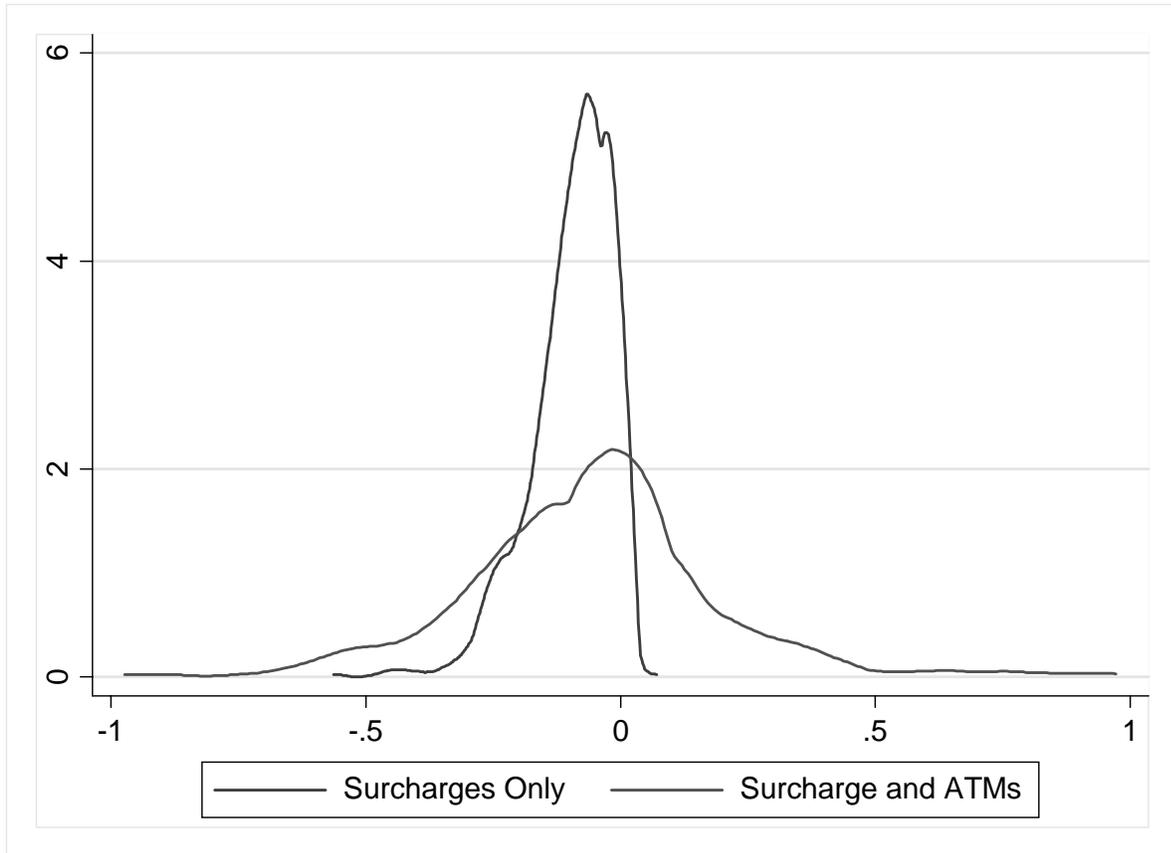


Figure 1: Kernel Density Estimate of County-Level Welfare Changes

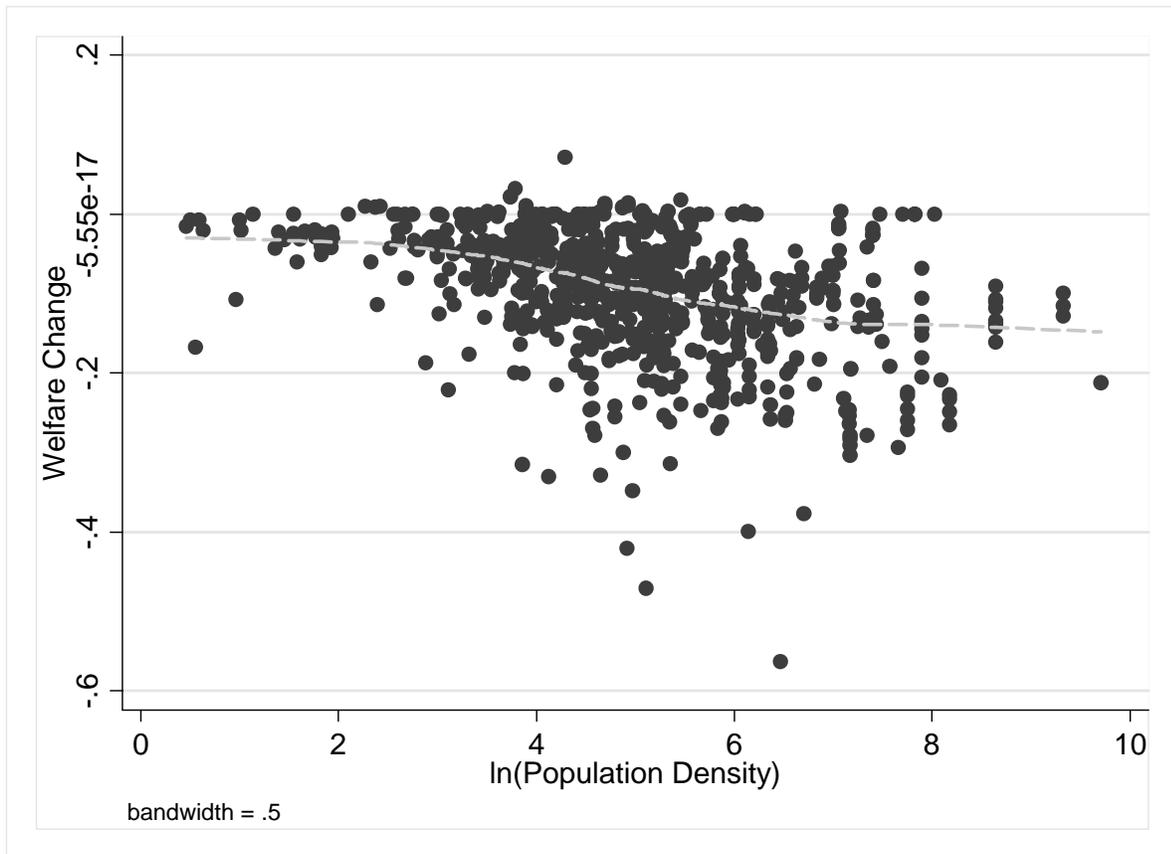


Figure 2: County-Level Welfare Changes and Population Density – Surcharging Only

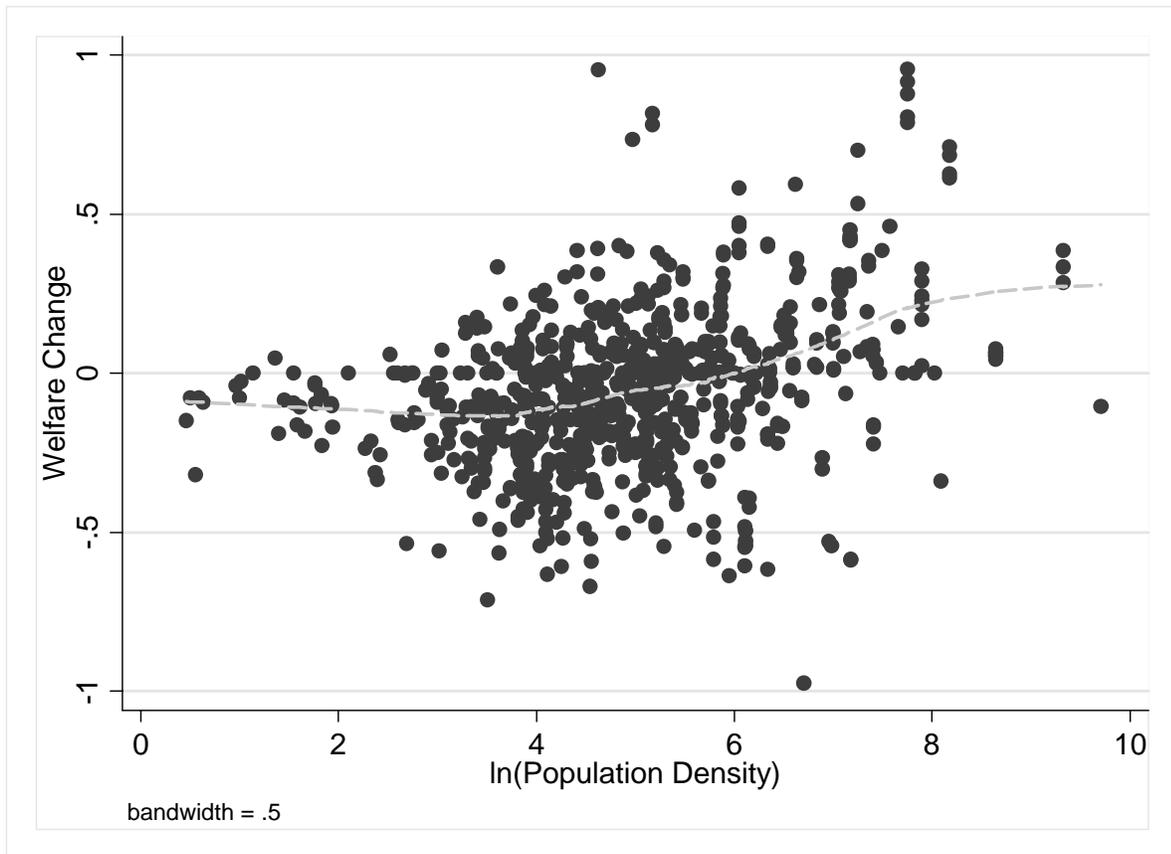


Figure 2: County-Level Welfare Changes and Population Density

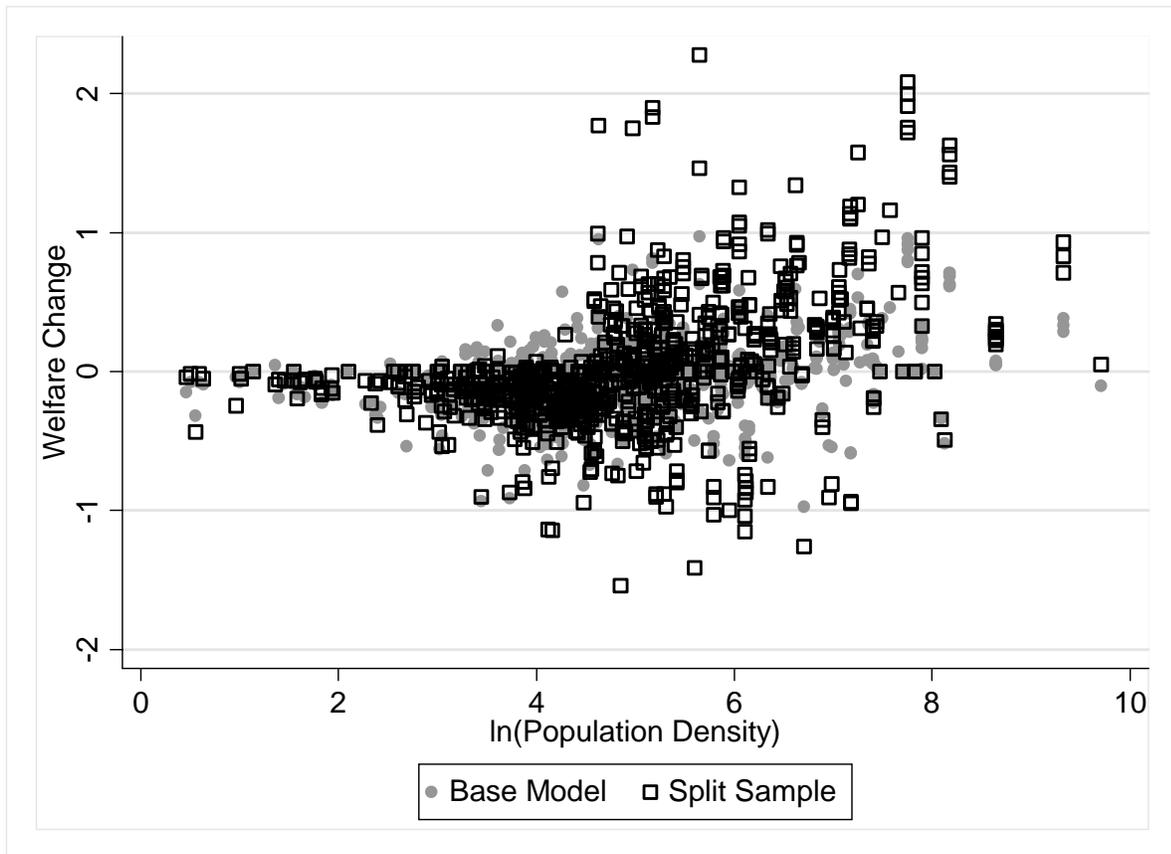


Figure 3: County-Level Welfare Changes For Base Model and Split Sample Model

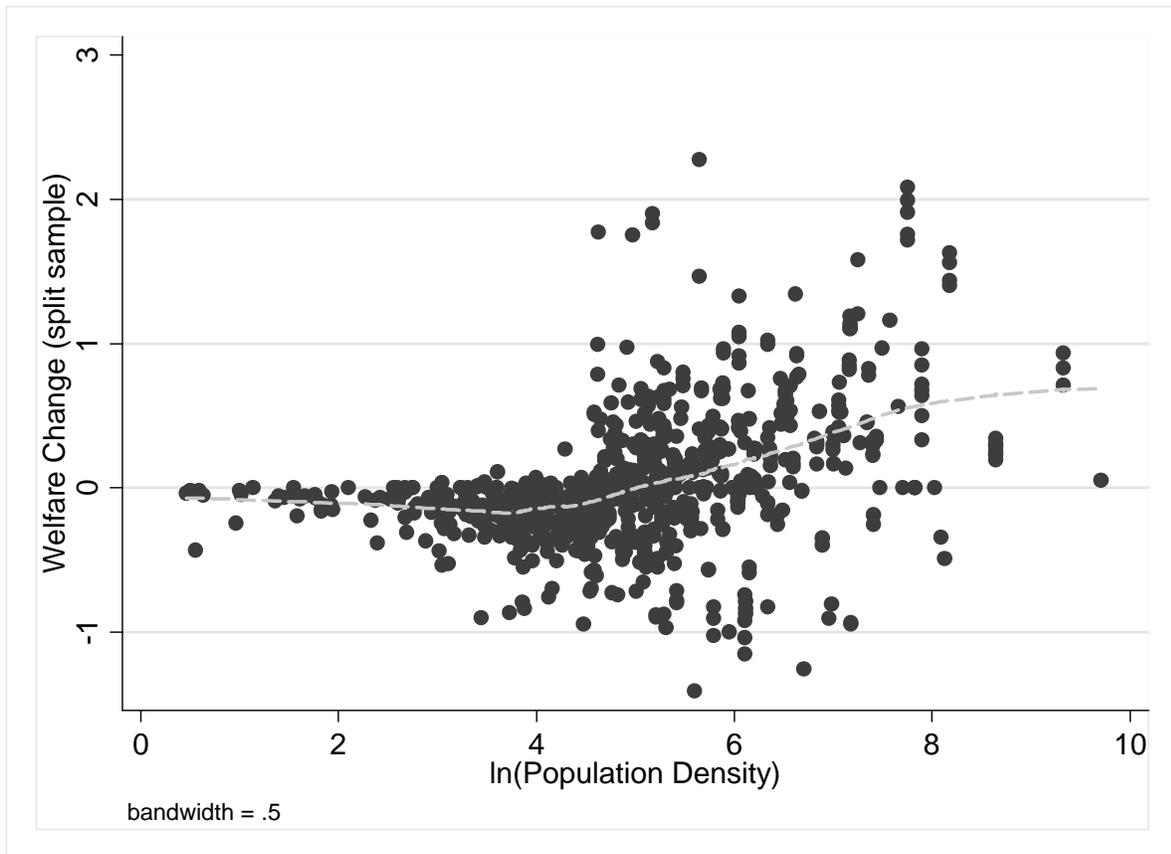


Figure 4: Split Sample Welfare Changes and Population Density