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Online Information and Offline Competition: The Emergence of Broadband Internet and Brick-and-Mortar Retailer Survival

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Abstract. This research examines how information access affects competition in offline markets. I study the relationship between broadband internet availability and brick-and-mortar retailer survival in the United States from 1999 through 2008, leveraging a period when competition from e-commerce channels was minimal and broadband's primary effect on retailers stemmed from reduced search costs. Using an instrumental variables estimation strategy that links broadband availability to local slope terrain, I find that broadband availability decreased the likelihood of retailer exit. These effects were more pronounced for retailers that faced higher discovery-related search costs *ex ante*, specifically young and independent establishments and those in dense or urban markets. The findings suggest that online information access can reshape offline competitive dynamics by altering consumer search and discovery.

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Keywords: search costs • market frictions • technology • internet • retail

Introduction

In markets characterized by search frictions, stimulating discovery is a fundamental challenge for firms (e.g., Oberholzer-Gee and Yao 2018, Rhodes and Zhou 2019). When collecting and sharing information about options in the market are costly, potential buyers may find it difficult to identify and evaluate sellers, and sellers, in turn, may struggle to connect to buyers. Under such circumstances, visibility can be a driver of competitive advantage, and the structure of competition is not only shaped by what firms offer but also by how easily they can be found (e.g., Chatain and Zemsky 2011, Mahoney and Qian 2013). When search frictions are disrupted, the competitive landscape can shift as changes in how consumers search for and select among offerings may determine which firms struggle and which firms thrive.

The emergence of widespread internet availability represents one such disruption. The internet has reduced search costs by increasing connectivity between and across firms and consumers and by changing how buyer-seller matching occurs (e.g., Bakos 1991, Brynjolfsson and Smith 2000). Before the internet, firms relied upon physical proximity; word of mouth; and print, radio, or television advertising to reach consumers. After the internet's emergence,

however, firms could now also leverage this novel channel to connect with consumers in a low-cost and decentralized manner. Put differently, the internet made it easier for firms to generate consumer awareness, reducing the search costs associated with discovery (hereafter, "discovery-related search costs"). This change in information access has revalued firm endowments related to visibility (e.g., Mahoney 2001, Brynjolfsson et al. 2011, Oberholzer-Gee and Yao 2018), thus creating asymmetries in firms' ability to adapt and compete in the new informational environment. Notably, by changing consumer search and discovery, the emergence of an online information channel has implications for competitive dynamics even in offline, brick-and-mortar settings.

Extant literature provides insights into consumer search behaviors in online markets (e.g., Brynjolfsson et al. 2011, Meyer et al. 2024, Raj 2024) and studies how competition from e-commerce channels affects retailer performance and strategy (e.g., Brynjolfsson and Smith 2000, Bennett et al. 2015). However, little is known about how online information availability affects offline competition by altering consumer search. This is an important gap in our understanding, particularly as new digital technologies continue to increase information availability (Lanzolla et al. 2020)

and firms in many industries still do most business offline (Lieber and Syverson 2012). In this research, I address this question by examining how the emergence of widespread broadband internet availability in the United States from 1999 through 2008 affected the survival of brick-and-mortar retail establishments. This setting provides a unique empirical sandbox. During this period, e-commerce adoption remained low,¹ and the primary effect of broadband availability on brick-and-mortar retailers was through a greater ability to share and access information (Bakos 1997, 2001). Accordingly, by examining when and how broadband availability affected the exit of brick-and-mortar retailers during this period, I generate insight into how online information availability and the resulting decrease in consumer search costs reshape offline competition.

Leveraging data on the population of U.S. retail establishments, I estimate the relationship between broadband availability and retailer survival. I utilize a validated instrument for broadband availability based on local slope terrain to address endogeneity concerns and produce a causal estimate of the effect of broadband availability on retailer exit (Kolko 2012, Chan et al. 2016). Although I lack direct data on consumer search behaviors, I search for evidence of a search cost-related mechanism by testing whether the relationship between broadband availability and exit varies based on factors that inform the costs that firms faced to generate consumer awareness *ex ante*. I consider how the relationship between broadband availability and exit is shaped by (a) establishment-specific endowments related to visibility, namely familiarity, as captured by chain status and age as well as pre-existing investments in accessibility and by (b) market characteristics that influence the nature of search, namely whether the establishment is operating in a dense and competitive market and whether the establishment is located in an urban area where informational search costs may be relatively more important and physical transaction costs less so.

Across the full sample, I find evidence that broadband availability decreases the likelihood of exit for retail establishments during this period. This result suggests that rather than leading to a more challenging competitive environment by destroying the value of existing investments or by increasing competitive pressure through greater price transparency, on average, this change was a driver of net economic growth and ecosystem stability. However, the relationship between broadband availability and the likelihood of exit is not uniform across the sample. Instead, the relationship between broadband availability and exit is larger in magnitude for establishments that faced higher costs to generate consumer awareness *ex ante*, consistent with the idea that local broadband

availability altered competitive conditions by reducing discovery-related search costs. Broadband availability was more beneficial to independent retailers, young retailers, and retailers that had not invested in visible locations as well as to retailers competing in denser markets or in urban areas, where information-related search costs were likely more important. These findings suggest that broadband availability reshaped local competitive conditions, benefiting establishments that could leverage the internet to stimulate consumer learning and facilitate discovery while increasing competitive pressures on those that previously leveraged information asymmetries to create a competitive advantage.

To strengthen the interpretation that broadband availability affected exit by reducing discovery-related search costs and to shed more light on how broadband availability changed competitive conditions, I conduct a series of additional tests. First, I show that productivity effects or labor market matchings are unlikely to explain the results, ruling out other mechanisms through which broadband availability may have affected exit. Second, I document that greater e-commerce exposure does not mitigate the documented effects, providing evidence that e-commerce substitution was not a meaningful threat to retailers during this period. Third, I establish that the relationship between broadband availability and exit is larger in higher-income and more-educated areas, perhaps because such areas were likely to be characterized by higher consumer broadband adoption. Finally, I present evidence that broadband availability was associated with greater entry among independent retailers and less entry among chain retailers, providing further support for the idea that online information access created a favorable environment for small businesses.

The results provide insights into how changes in information access can reshape the basis of competition by revaluing firm endowments that affect visibility and awareness. Although the empirical setting reflects a moment of technological transition in the United States, the findings are relevant in the present in many developing markets, where internet availability is limited (e.g., as of 2023, 65% of the population in developing nations lacks internet access) but diffusing rapidly (Broom 2023). Moreover, the findings inform how other technology changes that reshape information access, including mobile connectivity, artificial intelligence (AI)-enabled search and discovery tools, or metaverse-style settings, may alter competitive dynamics by changing consumer search. In each case, a firm's ability to benefit from technological change is likely to hinge on how well their strategic resources fit within the new informational environment.

The primary contribution of this research is to the literature documenting how search costs affect

competition (e.g., Chatain and Zemsky 2011, Rhodes and Zhou 2019). Although the literature studies consumer search behaviors on online channels (e.g., Brynjolfsson et al. 2011, Raj 2024) and how online sales and distribution channels affect offline performance (e.g., Pozzi 2013, Bennett et al. 2015), I extend prior work by documenting that online information may affect offline competition even without the threat of substitution. I contribute to the literature on how technological change revalues firm resources (e.g., Tripsas 1997, Cattani 2006) by showing that a technology-facilitated decrease in search costs can alter the strategic value of firm endowments, such as brand familiarity and location, creating competitive asymmetries. Further, these effects may differ across markets depending on the extent to which information-related search costs are an important friction. Finally, this study contributes to a broader literature on the effects of the internet and information technologies on economic outcomes (e.g., Forman et al. 2009, Czernich et al. 2011) by outlining the effect of broadband availability on retailer survival during the emergence of this technology. Despite fears that the internet hurt brick-and-mortar retailers by exposing them to e-commerce, the first-order effect was informational, benefiting firms positioned to capitalize on increased consumer awareness.

Related Literature

The Internet, Information Availability, and Search Costs

Prior to the emergence of the internet, consumers primarily learned about sellers through physical proximity, word of mouth, or information intermediaries, such as the Yellow Pages, local newspapers, business directories, or radio and television advertising (e.g., Westbrook and Fornell 1979, Lohrke et al. 2006). Relative to the postinternet era, this environment posed challenges for local businesses seeking to connect with consumers as search was more constrained. Stimulating consumer awareness may have been especially difficult for new or smaller firms that lacked brand recognition or marketing budgets and for those located in low-foot-traffic areas. Although information intermediaries, such as business directories, may have partially alleviated these challenges, they offered limited coverage, were not always easily accessible to consumers, and often favored firms with greater resources or prominence (Majumdar and Ramaswamy 1995, Hagiú and Jullien 2011). In such a context, visibility itself was an important strategic asset, and the cost of generating consumer awareness represented a barrier that shaped whether and how firms could compete, grow, or survive.

The emergence of the internet transformed how information was shared and accessed, introducing a

low-cost and democratized means for establishments to reach consumers. Firms could create their own web pages or take advantage of decentralized online intermediaries (e.g., Zhang 2009, Ofek et al. 2011) to communicate and share information with a broader swath of consumers (e.g., Sinai and Waldfogel 2004, Aldashev and Batkeyev 2021). Consumers could use the internet to learn about establishments that they had previously been unaware of using online search services, company websites, or community message boards or directories (Brynjolfsson et al. 2003, Adner et al. 2019). As a result, the emergence of the internet decreased the search costs associated with buyer-seller matching (Smith and Zentner 2015) and increased the likelihood that consumer search was successful (Chen et al. 2014). Importantly, these benefits were not evenly distributed. Firms that previously struggled with visibility or consumer awareness were well positioned to benefit from this shift, whereas those that leveraged market frictions and information asymmetries to create advantage faced new pressures.

Prior research has explored how the internet-enabled reduction in search costs has increased price competition (Bakos 1997, Lynch and Ariely 2000) while facilitating market expansion (Cachon et al. 2008) and can lead to product specialization (Rhodes and Zhou 2019) and long-tail effects (e.g., Brynjolfsson et al. 2011). A separate literature considers how the emergence of the internet elicited substitution or cannibalization of consumption from offline to online channels (e.g., Brynjolfsson and Smith 2000, Bennett et al. 2015, Chava et al. 2018).² However, we know little about whether and how the internet-facilitated increase in information availability heterogeneously affected offline firm performance in the absence of a meaningful threat from e-commerce channels. Understanding this dynamic would generate relevant insight today in many emerging markets that lack widespread internet access in the present (Broom 2023, Johnson 2024) and may also shed light on the implications of future innovations that increase information access, such as high-speed mobile networks, generative AI technologies, or the internet of things (Lanzolla et al. 2020).

To address this gap, in this research, I examine how the emergence of broadband internet availability from 1999 through 2008 affected the survival of brick-and-mortar retail establishments. By taking advantage of a period when firms faced little threat from e-commerce channels, I am able to focus on how the broadband-facilitated decrease in consumers search costs shaped competitive conditions. I first establish the average effect of broadband availability on retailer survival during the sample period. I then examine how this effect differs across establishments as this informational

shock altered the value of existing firm endowments (Tripsas 1997, Cattani 2006) and may have had differential effects based on the market that the firm operated in (e.g., Belenzon et al. 2019, Skiti 2020). As the benefits of a reduction in search costs should be highest when affected search costs are higher (e.g., Chung and Kalnins 2001, Raj 2024), I expect that broadband availability will be most beneficial for establishments that faced higher costs to generate consumer awareness *ex ante*. Below, I elaborate on this logic.

Heterogeneity Based on Establishment Endowments

Technology change may heterogeneously affect firms by altering the value of firm endowments or assets (e.g., Tripsas 1997, Cattani 2006). In the case of the broadband internet, the emergence of this technology may alter the value of endowments related to visibility. By lowering informational barriers that consumers face when searching for offerings, the internet enabled firms that previously struggled to find a market a novel way to reach consumers (e.g., Zentner et al. 2013, Kumar et al. 2014). Although highly recognizable and well-known firms benefit less from consumer learning as a result of a decrease in discovery-related search costs (Raj 2024), less-visible firms can take advantage of consumer access to information to connect to a novel audience and facilitate discovery (Chung and Kalnins 2001, Nagaraj and Reimers 2023). As such, establishments with less brand recognition, such as independent or young retailers, may benefit more from the changes in search facilitated by broadband availability.

Although broadband created new opportunities for previously overlooked firms, it also may have eroded the value of strategic investments aimed at generating visibility (Caldecott and McDaniels 2014). As online channels provide new, lower-cost ways for establishments to connect with consumers, investments designed to generate awareness may have been less likely to yield the same value. For example, although a retailer may have found that a premium location was a valuable asset prebroadband as it helped them reach customers, that same investment after broadband may have generated diminished returns as consumers altered search behaviors. Eroding the value of factors that differentiate establishments in the market will reduce a firm's ability to survive and thrive as an industry changes, creating a strategic disadvantage (Porter 1985, Amit and Zott 2001). Accordingly, establishments that have made *ex ante* investments to reduce discovery-related search costs through physical visibility may have been less likely to benefit from the information environment created by broadband availability.

Heterogeneity Based on Market Characteristics

Whether and how firms respond to technological change are also shaped by characteristics of the market that they operate in (e.g., Belenzon et al. 2019, Skiti 2020), and the strategic value of a decrease in discovery-related search costs will depend on the structure of the competitive environment. In markets featuring nonhomogeneous goods, search costs are higher when there is a greater number of firms as it can be difficult to have sufficient knowledge of all offerings (Stahl 1982, Baye et al. 2006). In crowded markets, an increase in information availability may be particularly valuable as consumers sort through a larger array of options and as establishments seek a way to differentiate from their peers and capture attention. In such settings, the internet may be a particularly important tool for stimulating consumer awareness and facilitating a better match between consumers and firms. Accordingly, the internet-facilitated reduction in discovery-related search costs may be more beneficial to brick-and-mortar retailers operating within more (versus less) crowded or competitive market segments.

A similar logic may manifest in considering how the effects of increased information availability may differ across geographic contexts. In dense urban areas, consumers have more choices and a more complex landscape of offerings. Further, because of the agglomerated nature of urban areas, transaction costs in such settings are more likely to revolve around the informational costs required to identify and evaluate potential options rather than the physical costs of visiting a given establishment (e.g., McCann and Folta 2009). In contrast, in nonurban areas, consumers may be more likely to be aware of the options accessible to them but may face meaningful transaction costs in the form of the physical search costs required to visit distantly located establishments. Given that broadband availability led to reductions in informational search costs (rather than physical transaction costs), it may have been more valuable to establishments operating in urban environments, where discovery-related frictions may be more salient.

Setting, Data, and Methodology

Empirical Setting

This research examines how the emergence of widespread broadband internet availability affected the survival of brick-and-mortar retailers (i.e., retail establishments competing in offline markets). This is an apt setting to study how an increase in information availability and a resultant reduction in discovery-related search costs affect offline performance. Direct-to-consumer brick-and-mortar retailers must make connections to consumers to stimulate demand, and the

emergence of the internet offered a new way for retail establishments to provide information to consumers, allowing them to connect directly with consumers through their own web pages or by sharing information through low-cost online intermediaries (e.g., Lohrke et al. 2006). Although fears regarding increased competition from e-commerce channels were present upon the emergence of this new technology (e.g., Stern and Weitz 1997), during the sample period, consumer adoption of e-commerce channels was low. Online retail sales made up less than 1% of total retail sales in the United States at the start of the sample time period in 1999 and had only risen to 3.6% at the end of the sample period in quarter 4 of 2008 (U.S. Census Bureau 2024). Further, the sample period focuses on a time when large e-commerce players (e.g., Amazon) and information intermediaries (e.g., Yelp! or Google Maps) were less salient. Accordingly, the setting enables a consideration of how the emergence of a no information channel affected retailer survival in relative isolation (in relation to other internet-enabled services or competition from e-commerce channels).

Sample and Measures

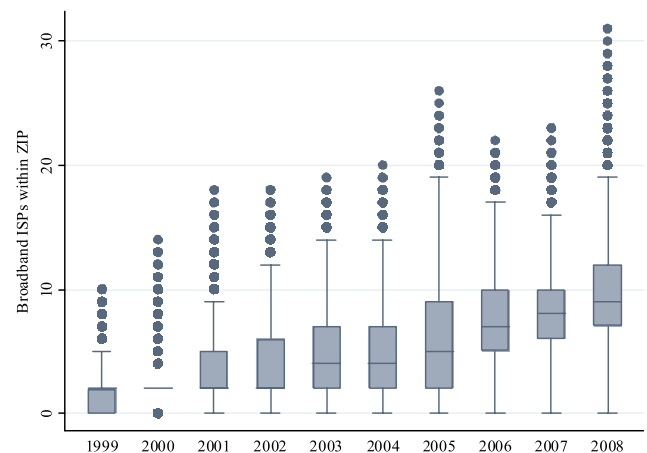
To study the relationship between broadband availability and brick-and-mortar retailer exit, I combine data from a variety of sources, including the Federal Communications Commission (FCC), the National Establishment Time Series (NETS) database, and the U.S. Census. The sample covers 1999–2008, spanning the nascent phase of diffusion through a period of widespread consumer adoption,³ and consists of approximately 6 million establishment-year observations across nearly 1.1 million unique retail establishments in the United States.

I use a zip code-level measure for the number of broadband providers supplying internet at 200 kilobits per second or faster to measure local broadband availability. These data are extracted from the FCC Form 477 and have been used as measures of internet availability in a range of prior work (e.g., Kolko 2012, Seamans and Zhu 2014, Chan et al. 2016). Following Chan et al. (2016), I focus on broadband access to internet rather than other forms of access (e.g., dial-up internet) as prior research suggests that broadband adoption is particularly likely to increase the usage of the internet (Hitt and Tambe 2007, Kolko 2010b). For example, broadband adoption increased usage of the internet by over 20 hours per month (relative to dial-up internet), and effects were even larger among those who previously had limited access to the internet (Hitt and Tambe 2007).⁴ Prior work also shows that the extent of residential broadband availability increases monotonically with the number of broadband internet service providers (ISPs) (Kolko 2010a, Chan et al. 2016), suggesting that the number of

providers is a meaningful measure of the penetration of broadband internet into localities. Following previous studies, I assign zip codes reported as having one to three providers as having two providers (Kolko 2012, Chan et al. 2016).⁵ Although this introduces measurement error into the analysis, the instrumental variables (IV) estimation to mitigate concerns regarding endogeneity also helps address such measurement error. Figure 1 displays the growth of broadband ISPs across zip codes during the sample period.

To measure retailer outcomes, I use NETS data. The NETS data (organized by Walls & Associates using underlying data from Dun and Bradstreet) consist of establishment-level longitudinal microdata covering the population of U.S. businesses. Such data have been used as an alternative to the U.S. Census data in studies in management, economics, and finance that study the performance of establishments across the United States (e.g., Becerra et al. 2020, Hegde et al. 2022). The sample for this research includes all establishments categorized as standard industrial classification (SIC) codes 53 (general merchandise), 56 (apparel and accessory), and 57 (home furniture, furnishings, and equipment). The decision to focus on this sample was guided by a desire to concentrate on retail segments often thought of as those susceptible to digital disruption during the early spread of the internet—consumer-facing retail establishments selling durable goods (Hortaçsu and Syverson 2015). Although the NETS data include yearly sales and employment figures, such data are often imputed and may be unreliable, particularly for small or independent establishments (Barnatchez et al. 2017). As such, I focus on survival as the main dependent variable in the analyses.⁶ Survival is a key measure of success in brick-

Figure 1. (Color online) Broadband Internet Service Providers over Time



Note. The figure shows a box-and-whisker plot of broadband internet service providers in zip codes within the United States from 1999 to 2008.

and-mortar settings and has been used as a proxy for retail performance in a number of studies (e.g., Raj and Eggers 2022, Sands 2025). Exit is a binary variable set equal to one in the last year of existence in the NETS data.

I consider how establishment- and market-level characteristics moderate the relationship between broadband availability and retail establishment exit. By exploring such heterogeneity, I (1) shed light on which firms benefit more or less from the emergence of broadband availability and (2) provide suggestive evidence that the effects that I document are likely to be driven by a reduction in discovery-related search costs. To this latter point, although I posit that broadband availability may shape retailer exit during this period primarily by altering consumer search costs, I lack direct data on consumer search behavior. However, by probing heterogeneity based on establishment and market characteristics that shape the search costs associated with discovery, I can evaluate whether the empirical patterns in the data are consistent with theoretical predictions regarding how a reduction in discovery-related search costs may affect establishment performance.⁷ At the establishment level, I consider how the relationship between broadband availability and exit depends on (a) establishment characteristics that inform familiarity and (b) investments in accessibility that facilitate discovery. At the market level, I consider how this relationship differs (a) based on market competition and (b) in urban versus all other areas.

I operationalize familiarity using two variables (*chain status* and *establishment age*) as both chain establishments and older establishments are more likely to be known by local consumers. I measure *chain status* by creating a categorical variable using the NETS data that dichotomizes retail establishments as stand-alone establishments (independent establishments with no related establishments defined through common ownership or shared brand), small chains (up to 100 related establishments), or large chains (more than 100 related establishments). I construct *establishment age* using the NETS data.

I capture investments in accessibility by capturing the “walkability” of each establishment’s location using data from the U.S. Environmental Protection Agency (EPA) (U.S. Environmental Protection Agency 2021). The *walkability index* is constructed at the census block level, incorporating intersection density, proximity to transit stops, and diversity of land uses. This measure captures how accessible or centrally located each establishment is, and establishments with a higher walkability have invested in a strategic resource that makes them easier to access. Rent and physical retail space are sticky investments for brick-and-mortar retail establishments (e.g., Clarke et al. 1997, Reynolds and Wood 2010), and thus, such investments may be difficult to quickly unwind as the environment

changes. Although the measure provided by the EPA ranges from 1 to 20, I standardize it to a mean of 0 and a standard deviation of 1 for presentation in regression tables.

I operationalize market competition using *same-industry establishment density* defined as the log-transformed count of establishments in a four-digit SIC code operating within a zip code. To account for outliers in the data, I winsorize the same-industry establishment density variable at the 1st and 99th percentiles.⁸ I identify urban markets using the 2000 rural-urban commuting area (RUCA) codes provided by the U.S. Department of Agriculture. The RUCA codes identify metropolitan, micropolitan, small town, and rural commuting areas, and I define urban areas as zip codes categorized as a core metropolitan area.

I use a number of control variables in the analyses. I control for all moderator variables defined above; *industry* using the SIC4 codes provided in the NETS data; economic and demographic conditions at the county level—*average income*, *unemployment rate*, and *population*—using data collected by the U.S. Census Bureau; the *county-level housing price index* from the Federal Housing Finance Agency to account for local real estate conditions; the *log-transformed total count of retail establishments* within the zip code winsorized at the 1st and 99th percentiles to further account for local competition; and establishment age. Table 1 contains summary statistics of all variables used in the analyses.⁹

Estimation Strategy

In the main analysis, I estimate the likelihood of establishment exit using an ordinary least squares (OLS) linear probability model (LPM). Although models utilizing right-censored data or absorbing outcomes (such as exit) often use hazard model specifications, I use the LPM in my main analyses for the following reasons. (1) Hazard models rely upon the proportional hazards assumption, which assumes that the effect of a variable on the hazard of an event is time invariant and is unlikely to be met in this setting. (2) The instrumental variables estimation strategy used to address endogeneity concerns can more easily be estimated with an LPM, and the use of an OLS LPM in the main analysis allows for easier comparison across estimates. (3) LPMs allow for high-dimensional fixed effects, which are less computationally feasible in hazard models. (4) LPMs provide simple and interpretable results (Greene 2003, Angrist and Pischke 2009).¹⁰ I estimate equations of the following form:

$$\begin{aligned} \text{Exit}_{ijt} = & \beta_1 \text{Broadband}_{jt} + \beta_2 C_{it} + \text{Zip FE}_t + \text{Year FE}_t \\ & + \text{Industry FE}_i. \end{aligned} \quad (1)$$

In this equation, i indexes the establishment, j indexes the zip code, t indexes the year, and k indexes

Table 1. Summary Statistics

Panel A: Establishment-level statistics		Panel B: Establishment-year statistics								
	Count	Minimum	10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile	Maximum	Mean	Standard deviation
No. of unique establishments	1,093,498	0	0	0	0	0	0	1	6.9%	25.3%
Establishment type		0	2	5	9	13	15	31	8.9	5.0
Stand-alone establishment	863,752	0.000	0.000	0.004	0.161	1.626	7.455	59,837	2.2	4.9
Small chain	85,529	0	0	2	6	11	15	19	7.0	5.5
Large chain	144,217	-2.5	-1.3	-0.8	0.1	0.9	1.3	2.0	0.0	1.0
Sector		0	26,533	30,882	37,197	44,199	51,501	101,084	38,617	11,189
SIC53: General merchandise stores	113,569	0.7	3.2	4.0	4.9	5.9	7.1	30.6	5.1	1.6
SIC56: Apparel and accessory stores	450,297	0	44	143	528	1,447	2,942	9,793	1,301	2,183
SIC57: Furniture and home furnishings stores	529,632	-44.8	-1.8	2.0	4.7	9.4	15.1	55.9	5.6	8.1
Urban designation		2	15	36	71	123	185	410	90.1	75.7
Urban core	884,654	1	1	3	5	11	20	713	10.0	23.6
All other	208,844									

Notes. The table reports establishment-level and establishment-year-level summary statistics for sample observations. Note that location designation data are missing for 176 establishments. HPI, housing price index.

the industry. The dependent variable is a binary indicator that takes the value of one if an establishment exits in year t . The main independent variable, *Broadband*, measures the count of broadband ISPs offered in a zip code in year t . The term C refers to the vector of establishment-year controls described above, *Year FE* refers to year fixed effects (to control for common time effects), and *Industry FE* refers to industry fixed effects (to control for common industry-level effects).¹¹ Standard errors are clustered at the county level to account for correlation across establishments in similar retail catchment areas.

A simple examination of the correlation between internet availability and retail establishment exit cannot be interpreted causally. This is because the availability of broadband internet within a locality may be affected by factors that may also influence retail establishment performance or exit. For example, areas experiencing more rapid economic growth may also see greater growth in broadband internet providers, and if this is the case, any relationship between internet availability and retail establishment survival could instead be driven by the effects of per-capita wealth. As a first step to address these concerns, I control for observable factors that could be related both to the availability of broadband internet and to the performance of retail establishments, such as average income or local population. However, although this may address concerns about the most obvious confounding factors, estimates may still be biased as unobservable characteristics may affect both internet availability as well as retailer performance.

To address such concerns, I utilize an instrumental variables estimation strategy. An IV estimation relies on the use of an instrument that is correlated with the independent variable (the relevance condition) but has no direct effect on the outcome of interest (the exclusion restriction). If these conditions are met, the IV strategy can be used to estimate the effect of the independent variable on the outcome of interest (Greene 2003). I instrument for growth in the number of broadband internet providers within a zip code using the slope of the local terrain (Kolko 2012, Chan et al. 2016). The slope instrument identifies cross-sectional variation in the cost of extending broadband internet service to an area, and as noted in previous literature, terrain features, such as slope, affect the costs of providing broadband service to an area (Prieger 2003, Government Accountability Office 2006). Broadband service providers face high cost barriers to providing service in areas with steep terrain, and accordingly, there is a negative relationship between terrain slope and the growth of broadband internet providers within a locality (Chan et al. 2016).

To estimate the effects of broadband penetration using the IV estimation strategy, I estimate an OLS

first-stage equation to predict the count of broadband internet providers within a zip code with the slope terrain of that zip code interacted with a linear time trend. I note that this is a slightly distinct approach from prior studies, which use time indicator variables rather than a linear time trend (Kolko 2012, Chan et al. 2016). The rationale for not using the categorical interaction is twofold. First, the categorical interaction produces a set of weak instruments, with a first-stage F -statistic of 7.570, falling underneath the rule of thumb of 10 and the relevant Stock–Yogo critical values. Second, the categorical interaction fails Hansen’s overidentification test, indicating that the instruments are correlated with the residuals and casting doubt on the exogeneity of the instrument. With a single endogenous independent variable (the count of ISPs) and 10 instruments generated by interacting slope with year dummies, the categorical interaction may overidentify in the first stage, risking both a weak instrument problem with many diluted instruments and the chance of overfitting, which can violate exclusion restrictions. The more parsimonious approach with a single instrument (i.e., slope interacted with the linear time trend) exhibits a stronger first stage and is less likely to be overidentified, thus making it a better fit for this research.¹² Essentially, the selected first-stage equation uses cross-sectional variance in terrain slope to predict the rate of growth in broadband availability in a locality across the sample. I then use the predicted values in the second-stage equation to estimate the effect of broadband availability on retail establishment exit.

The instrument satisfies the relevance condition. I find a strong first-stage relationship between the instrument and broadband availability (Table A2 in the Online Appendix), with an F -statistic of 25.8 for the fully specified first-stage model. Areas with steeper terrains experience slower growth in the number of broadband ISPs. The exclusion restriction holds if terrain slope does not affect retail establishment exit independent of its relationship with broadband availability and cannot be tested directly. There may be concerns that terrain characteristics may have indirect effects that shape the likelihood of establishment exit. For example, terrain slope could affect retail establishment survival through its relationship with urban development or economic characteristics (e.g., Glaeser and Sacerdote 1999). To the extent that terrain slope is linked to time-invariant observable or unobservable local characteristics that influence the likelihood of establishment exit, all models include zip-level fixed effects that account for such variation. Perhaps more worrying would be the idea that terrain slope may lead to differential trends related to competitive conditions that would not be absorbed by the zip-level fixed effects. These concerns may be justified given

that there is evidence that broadband is linked to economic growth (Kolko 2012), which could mean that any results may be capturing the effect of growth rather than broadband availability.

I take several steps to combat concerns that the exclusion restriction may be violated. First, I include controls for demographic and economic conditions, including the population, unemployment rate, household income, and housing price index, that should account for time-varying economic or demographic conditions that may be correlated with both broadband availability and establishment exit. Second, to specifically consider whether the results that I document may be driven by economic growth, I conduct a split-sample analysis that documents the effects of broadband availability in high-growth versus low-growth zip codes, which are defined as zip codes with an above-median versus below-median growth in median household income during the sample period, respectively. To the extent that the results that I document are driven by economic growth, I would not expect to find an effect of broadband availability in low-growth zip codes. However, the results of this analysis (Table A3 in the Online Appendix) find a consistent relationship between broadband availability and exit across low- and high-growth areas, suggesting that the documented relationship between broadband availability and exit is unlikely to be accounted for by growth. Third, I compare reduced form models that regress the instrument against establishment exit for two sample periods: 1990–1998, representing a presample period before widespread broadband availability, and 1999–2008, representing the main sample period (Table A4 in the Online Appendix). I find no significant correlation between the instrument and exit during the presample period, suggesting that the instrument has no relationship with the likelihood of exit in the period before broadband emergence, but I do find a significant relationship between the instrument and exit during the sample period. The difference in inference before and after the widespread broadband rollout provides further suggestive evidence that broadband availability is the causal pathway underlying the IV estimates. Although it may not be possible to claim that slope terrain is truly independent of establishment exit outside of its relationship with broadband availability, with the evidence presented in these tests, I believe that the IV estimates can be interpreted as a causal estimate of the effect of local broadband availability conditional on the assumption that the controls mitigate possible violations of the exclusion restriction.

Although I first estimate the average effect of broadband availability on establishment exit, the focus of this research is exploring heterogeneity in this relationship to better understand how broadband-facilitated

information availability may differentially affect firms. Accordingly, I consider how the relationship between broadband availability and establishment exit differs based on establishment characteristics as outlined above. I do so by interacting each of the considered moderators with the measure of broadband availability in the OLS specification and testing for the significance of the interaction effect. For this analysis, as I utilize interaction terms to evaluate heterogeneous effects, the risk associated with omitted variable bias is reduced (Nizalova and Murtazashvili 2016, Bun and Harrison 2019).

Main Results

Average Effect of Broadband Availability

Table 2 presents the results estimating the average effect of local broadband availability on brick-and-mortar retail establishment survival using the OLS estimation (columns (1)–(3) in Table 2) and the IV estimation (columns (4)–(6) in Table 2). In columns (1) and (4) in Table 2, I document the relationship of broadband availability on retail establishment exit just controlling for zip code, year, and industry fixed effects before adding in controls for establishment characteristics (columns (2) and (4) in Table 2) and local demographic and economic conditions (columns (3) and (6) in Table 2). The OLS specification does not find a significant relationship between broadband availability and exit in columns (1) and (2) in Table 2. However, the fully specified OLS model (column (3) in Table 2) suggests that each additional broadband ISP is correlated with a 0.04-percentage-point decrease in the likelihood of exit ($p < 0.01$). When scaled by the unconditional sample mean likelihood of exit (6.9%), this suggests that each additional broadband ISP is correlated with a 0.6% decrease in the likelihood of exit. Using the IV specification (columns (4)–(6) in Table 2), I find a negative relationship between broadband availability and the likelihood of establishment exit across all specifications. This estimate is consistent in magnitude across columns (4) and (5) in Table 2 ($\beta = -0.006, p < 0.01$), but it grows in column (6) in Table 2 with the addition of local and demographic controls ($\beta = -0.012, p < 0.01$). The fully specified IV estimate (column (6) in Table 2) suggests that each additional broadband ISP decreases the likelihood of exit by 1.2 percentage points, equivalent to a 17.4% decrease in the likelihood of exit when scaled by the sample mean.¹³

The change in magnitude in column (6) in Table 2 relative to columns (4) and (5) in Table 2 is driven by the inclusion of the control for local retail density as estimates obtained from IV specifications that do not include this control are smaller in magnitude. This may reflect that local retail density is correlated with

Table 2. Estimates of the Effect of Broadband Availability on Retail Establishment Exit

Specification Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
	<i>Exit</i>	OLS <i>Exit</i>	<i>Exit</i>	<i>Exit</i>	IV <i>Exit</i>	<i>Exit</i>
Count ISPs	0.0000 (0.0001)	−0.0001 (0.0001)	−0.0004** (0.0002)	−0.0055*** (0.0014)	−0.0064*** (0.0015)	−0.0122*** (0.0028)
Age		−0.0015*** (0.0000)	−0.0014*** (0.0000)		−0.0016*** (0.0000)	−0.0015*** (0.0000)
Small chain		−0.0030*** (0.0006)	−0.0031*** (0.0006)		−0.0034*** (0.0006)	−0.0037*** (0.0006)
Large chain		−0.0274*** (0.0006)	−0.0273*** (0.0006)		−0.0277*** (0.0006)	−0.0279*** (0.0006)
Walkability index		−0.0006** (0.0003)	−0.0005* (0.0003)		−0.0007** (0.0003)	−0.0006* (0.0003)
Log average income			0.0089 (0.0117)			0.0130 (0.0231)
Unemployment rate			0.0013** (0.0006)			0.0033** (0.0013)
Log population			−0.0089*** (0.0019)			−0.0045 (0.0038)
Percentage change HPI			0.0002*** (0.0001)			0.0007** (0.0003)
All retail establishment density			0.0432*** (0.0029)			0.0562*** (0.0048)
Same industry establishment density			0.0009*** (0.0003)			0.0012*** (0.0003)
Zip fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
SIC4 fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
No. of establishments	1,093,294	1,093,293	1,085,803	1,081,032	1,081,031	1,073,583
Weak instrument <i>F</i> -statistic	N/A	N/A	N/A	38.4	38.4	25.8
<i>R</i> ²	0.015	0.017	0.017	N/A	N/A	N/A
Establishment-year observations	6,018,520	6,018,510	5,952,582	5,949,581	5,949,571	5,884,162

Notes. The table reports the results of estimating the effect of broadband availability on the likelihood of retail establishment exit. Columns (1)–(3) are estimated using an OLS specification. Columns (4)–(6) are estimated using an instrumental variable specification. More details about the specifications and variables used in the analysis are provided in the text. Standard errors clustered at the county-level are shown in parentheses underneath the coefficient estimates. HPI, housing price index; N/A, not applicable.

*Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level.

both broadband availability and establishment exit. By controlling for retail density, which is correlated with competitive pressure, I isolate the effect of variation in broadband ISP availability accounting for local competition. However, the instability of the coefficient of IV estimate following the introduction of this control raises the possibility of a violation of the exclusion restriction as it could suggest that the instrument may affect exit through its relationship with local retail density as well as through its relationship with broadband availability. As noted above, the IV estimate can be interpreted as a causal estimate of the effect of broadband availability conditional on the assumption that the controls adequately address potential violations of the exclusion restriction. As I cannot test this assumption, I acknowledge that it is not possible to

completely rule out concerns regarding violations of the exclusion restriction. However, given that the reduced form does not produce a significant estimate in the prebroadband period (Table A4 in the Online Appendix), when terrain slope may still have affected exit through retail density, I believe that it remains likely that the IV estimates are capturing the effect of broadband availability rather than retail density.¹⁴

Readers may also notice that the IV estimates are much larger in magnitude than the OLS estimates.¹⁵ This difference could emerge for two reasons. First, the OLS estimates may be biased because of omitted variables. For example, if broadband expanded more rapidly in competitive retail markets where turnover is likely to be higher, OLS estimates specification may feature downward bias. This may be likely to be the

case as broadband availability is positively correlated with a number of factors that may proxy for or contribute to the competitiveness of a retail market, including urban designations, accessibility, income, population, and establishment density (see Table A1 in the Online Appendix).

Second, the IV estimation strategy recovers a local average treatment effect (LATE) and not an average treatment effect (ATE). This means that the IV estimates identify the effect of broadband availability only for the subpopulation of retail establishments located in “marginal” areas where growth in broadband availability is affected by terrain and not for establishments located in areas where broadband was always likely to be available (e.g., large urban areas) or unavailable (e.g., extremely sparsely populated areas). An important implication of this is that the IV estimates, being LATEs, cannot necessarily be generalized to the average establishment. LATEs may overstate the ATE of broadband availability if effects are smaller in nonmarginal areas. This may be the case in the empirical setting as the effect of broadband availability may be smaller in localities that had greater broadband availability at an early period or where broadband did not establish a foothold during the sample period regardless of terrain.

To explore whether this may be the case empirically, I examine how the effect of broadband availability differs in zip codes that had lower versus higher broadband availability at the beginning of the sample period. Zip codes with higher broadband availability, which I define as the 75th percentile and above, at the start of the sample may be considered nonmarginal areas, where broadband was widespread early and growth was fast regardless of the slope terrain. Accordingly, if the effect of broadband availability is smaller in such areas, it would provide suggestive evidence that the difference in effect sizes between the OLS and IV estimates could be driven by differences between the ATE and the LATE. Indeed, I find that the relationship between broadband availability and exit is larger in magnitude and has greater statistical power in areas that had lower broadband availability (Table A6 in the Online Appendix). This result appears consistent with the idea that the LATE captured by the IV estimates may overstate the ATE across the full population of establishments by overweighing the effect of broadband availability in marginal areas.

Heterogeneity by Establishment and Market Characteristics

The results thus far suggest that broadband availability decreases the likelihood of brick-and-mortar establishment exit. Although this average effect is noteworthy empirically, the focus of this research is

on evaluating heterogeneity to shed light on how increased information availability may differentially affect establishments competing in an offline market. I consider how the effect of broadband availability differs by establishment endowments (chain status, establishment age, and investments in accessibility) as well as market conditions (establishment density and urban designation) that shape the search costs that establishments face. Table 3 presents the results of this analysis using the OLS specification by testing how the relationship between broadband availability and exit is moderated by the factors listed above. I explore heterogeneity in the relationship between broadband availability and exit using the OLS specification as the OLS is easy to interpret, provides an estimate of the ATE for the full sample rather than the LATE for instrument-affected establishments, and allows for the testing of multiple moderators simultaneously. Moreover, when estimating heterogeneous effects using interaction terms, interaction coefficients are less sensitive to omitted variable bias than main effects (Nizalova and Murtazashvili 2016, Bun and Harrison 2019), mitigating one of the key concerns typically addressed through an IV estimation strategy. Although implementing the same interaction structure with the IV estimation is not straightforward, as each interaction term becomes an additional endogenous regressor, I use a split-sample approach to document heterogeneous results with the IV specification in Table A7 in the Online Appendix. The results obtained using the split-sample IV estimation are consistent with those obtained by the OLS estimation.¹⁶

I first consider how the relationship between broadband availability and establishment exit is moderated by establishment-specific endowments. In column (1) in Table A7 in the Online Appendix, I show that chain status moderates the relationship between broadband availability and the likelihood of exit ($p < 0.01$ for both interactions). Using the linear combination of interaction effects and scaling by the unconditional sample mean, the estimates suggest that an increase of one broadband ISP within a zip code is associated with a 1.4% decrease in the likelihood of exit for independent retail establishments ($p < 0.01$) relative to 0.6% ($p = 0.016$) and 2.2% ($p < 0.01$) increases for small and large chain retail establishments, respectively. In column (2) in Table A7 in the Online Appendix, I present evidence that establishment age positively moderates the relationship between broadband availability and establishment exit ($p < 0.01$) as an increase in one broadband ISP within a zip code is associated with a 2.1% decrease in the likelihood of exit for a 2-year old firm (25th percentile) relative to a 0.6% increase for an 11-year old firm (75th percentile; $p < 0.01$ for both). In column (3) in Table A7 in the Online Appendix, I do

Table 3. Estimates of the Heterogeneous Effect of Broadband Availability on Retail Establishment Exit

Dependent variable	(1) <i>Exit</i>	(2) <i>Exit</i>	(3) <i>Exit</i>	(4) <i>Exit</i>	(5) <i>Exit</i>	(6) <i>Exit</i>
Count ISPs	−0.0010*** (0.0002)	−0.0019*** (0.0002)	−0.0004** (0.0002)	0.0000 (0.0002)	0.0013*** (0.0002)	−0.0004* (0.0002)
Count ISPs × ...						
Small chain	0.0014*** (0.0001)					0.0010*** (0.0001)
Large chain	0.0025*** (0.0001)					0.0023*** (0.0001)
Age		0.0002*** (0.0000)				0.0002*** (0.0000)
Walkability index			0.0000 (0.0001)			0.0001 (0.0001)
Same industry establishment density				−0.0002*** (0.0001)		−0.0001* (0.0001)
Urban					−0.0017*** (0.0001)	−0.0018*** (0.0001)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Zip fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
SIC4 fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes
No. of establishments	1,085,803	1,085,803	1,085,803	1,085,803	1,085,803	1,085,803
R ²	0.017	0.018	0.017	0.017	0.017	0.018
Establishment-year observations	5,952,582	5,952,582	5,952,582	5,952,582	5,952,582	5,952,582

Notes. The table reports the results of estimating the heterogeneous effect of broadband availability on the likelihood of retail establishment exit. This table presents the results of considering the effect of broadband availability based on (a) stand-alone vs. chain status, (b) firm age, (c) establishment's score on the walkability index, (d) same industry establishment density, and (e) urban location designation. More details about the specifications and variables used in the analysis are provided in the draft. All estimates include the full set of controls included in Table 2. Standard errors clustered at the county-level are shown in parentheses underneath the coefficient estimates.

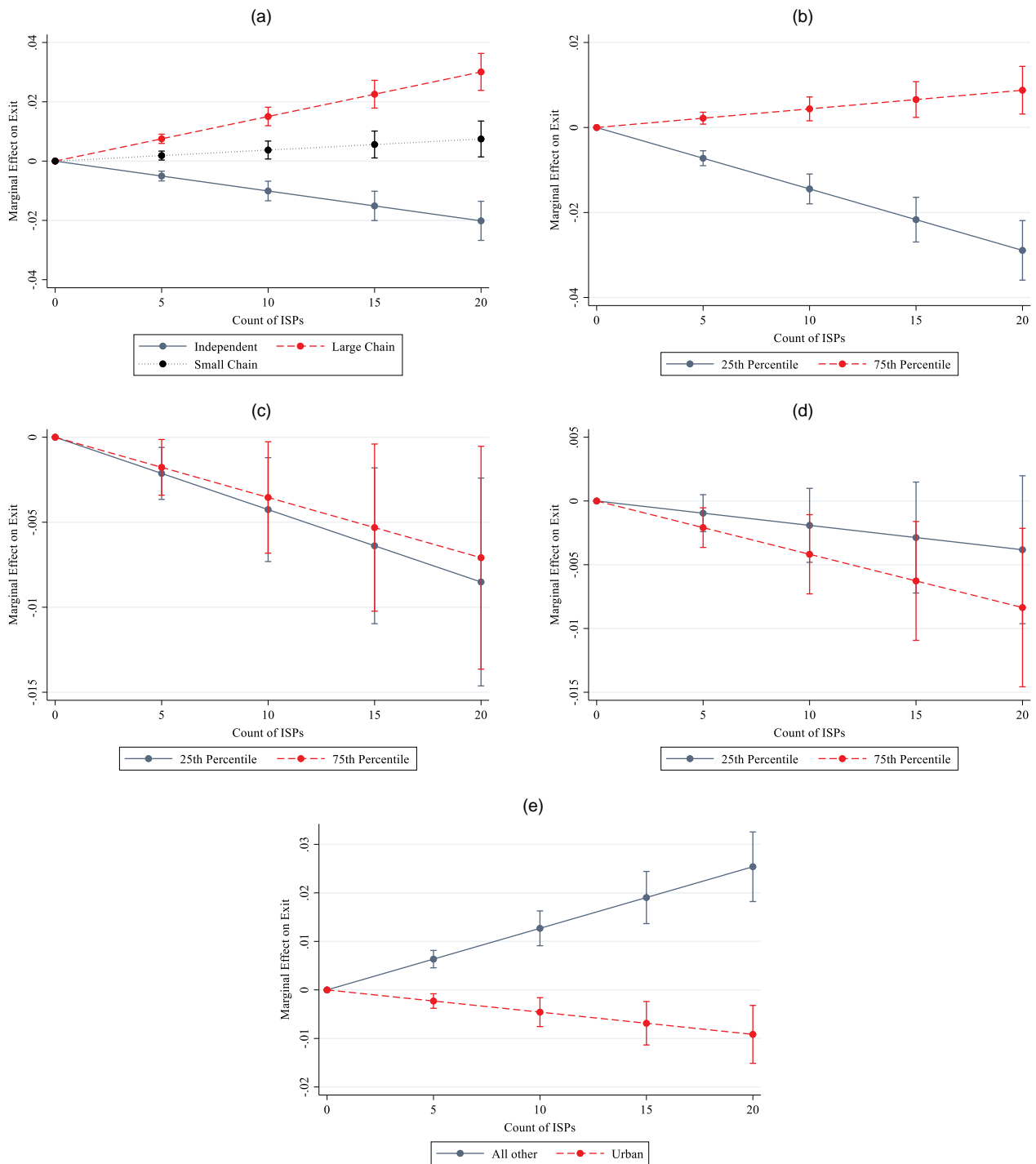
*Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level.

not find evidence that the relationship between broadband availability and establishment exit is moderated by investments in accessibility as captured by the walkability index ($p = 0.485$). Given this nonresult, I further probe the moderating role of walkability in additional analyses (Table A8 in the Online Appendix). I consider a model that converts the walkability measure into a quartile indicator and do find that bottom-quartile walkability establishments benefit the most from broadband availability. Further, as walkability may be higher in urban locations, I examine the moderating effect of walkability in urban versus nonurban locations. I find that the positive moderating effect of walkability is present in both subsamples and larger in nonurban locations. Together, these results point to the imperfection of walkability as a measure in this setting, particularly in comparing urban versus nonurban settings, but they provide some evidence that investments in locations are devalued following greater broadband availability.

I next consider how the relationship between broadband availability and establishment exit is moderated by market-level characteristics. In column (4) in Table A7 in the Online Appendix, I show that local market

competition moderates the relationship between broadband availability and exit ($p < 0.01$). In zip codes with low same-industry establishment density (25th percentile), an additional broadband ISP does not have a significant relationship exit ($p = 0.196$), whereas in zip codes with high same-industry establishment density (75th percentile), each additional broadband ISP is associated with a 0.6% decrease in the likelihood of exit ($p < 0.01$). In column (5) in Table A7 in the Online Appendix, I show that the negative relationship between broadband availability and establishment exit is driven by retailers located in urban zip codes ($p < 0.01$). Each additional broadband ISP is associated with a 1.8% decrease in the likelihood of exit for retailers in urban zip codes and a 0.7% increase in the likelihood of exit for retailers in nonurban zip codes ($p < 0.01$ for both). All moderation results persist in a saturated model including all moderators (column (6) in Table A7 in the Online Appendix), although the moderation by same-industry establishment density becomes marginally significant ($p = 0.087$). The heterogeneous effects of broadband availability across considered moderators are presented graphically in Figure 2.

Figure 2. (Color online) Heterogeneous Effect of Broadband Availability on Exit



Notes. This figure plots the marginal effect of an increase in broadband ISPs within a county on retail establishment exit for the moderators considered in Table 3. For continuous moderators, estimated effects are shown at the 25th and 75th percentiles of the moderator variables. (a) Chain status. (b) Age. (c) Walkability index. (d) Market competition. (e) Urban vs. all other locations.

These results add nuance to the baseline estimates. I find evidence that the negative relationship between broadband internet availability and the likelihood of establishment exit is larger in magnitude for establishments that ex ante may have faced higher

information-related search costs, such as new entrants and independent businesses. In contrast, establishments that could leverage market frictions to generate a competitive advantage—such as older, entrenched, and chain retailers—were actually *more* likely to exit

as broadband availability increased. Further, the results suggest that the negative relationship between broadband availability and establishment exit is larger in magnitude for retailers in dense competitive environments and in urban localities, reflecting the relative importance of informational search costs in such locations. Together, the results are consistent with an interpretation that the emergence of broadband availability affected firm survival by shaping discovery-related search costs for consumers.

Additional Analyses

Mechanism Tests

As noted, my ability to test the underlying search cost mechanism posted is limited because I lack data on consumer search behavior. However, I conduct a series of analyses to address alternative explanations and to shed light on how the effect of broadband availability on retailer survival manifests in this

setting. I summarize these tests in Table 4 and describe them in more detail below.

First, I address whether the results may partially or entirely reflect the relationship between broadband availability and productivity (e.g., Grimes et al. 2012, Barrero et al. 2023). Although I lack detailed data on establishment productivity, I proxy it using revenue per employee as captured by the NETS data. As noted above, NETS revenue and employment data may be unreliable (Barnatchez et al. 2017), so I do not use sales or employment as outcome or control variables in main specifications. However, to the extent that it is directionally accurate, it serves as a noisy proxy of establishment productivity. Within the data, I find a positive relationship between broadband availability and this measure using the OLS specification, and I find no meaningful relationship using the IV specification (Table A9 in the Online Appendix). However, main and heterogeneous results persist controlling for

Table 4. Summary of Mechanism Tests

Motivating question	Summary of test and results	Tables
Does increased labor productivity play a role in explaining the documented results?	Although broadband availability is linked to increased productivity, main and heterogeneous results persist controlling for productivity, suggesting that it is unlikely to drive the results.	Tables A9 and A10 in the Online Appendix
Does employer-employee matching play a role in explaining the documented results?	Broadband availability is not moderated by labor market tightness, and heterogeneous effects persist controlling for the interaction between labor market tightness and broadband availability.	Table A11 in the Online Appendix
Is there further evidence that the documented effects are driven by discovery-related search costs?	The relationship found in the full sample, where younger firms benefit more from broadband, holds for independents and small chains, for which discovery-related search costs may be more pertinent. For large chains that are more likely well known to consumers, this moderation flips, and older firms benefit more from broadband availability.	Table A12 in the Online Appendix
What role, if any, does e-commerce exposure play during this time period?	OLS models suggest that establishments with greater e-commerce exposure benefitted more from broadband availability, whereas IV estimates suggest no significant moderation. The results are inconsistent with an e-commerce substitution mechanism. However, it is possible that during this time period, e-commerce exposure may be associated with greater online search and comparison, thus amplifying positive effects.	Table A13 in the Online Appendix
How might the effects of broadband availability be shaped by consumer adoption or usage?	The effect of broadband availability is larger in higher-income and more-educated localities, where consumers may be more familiar with and likely to use the technology upon its availability.	Table A14 in the Online Appendix

Note. This table summarizes a series of mechanism tests taken to better understand the relationship between broadband availability and retail establishment exit.

revenue per employee (Table A10 in the Online Appendix), suggesting that productivity is unlikely to be a key driver of the results.

Second, I evaluate whether internet-facilitated employer-employee matching (Poliquin 2021) plays a role in explaining the results. To do so, I consider how the unemployment rate moderates the relationship between broadband availability and establishment exit, with the logic that this mechanism should be more important in tight labor markets when unemployment rates are low. I find no evidence that the unemployment rate moderates the relationship between broadband availability and exit (Table 11 in the Online Appendix), and both the baseline and heterogeneous effects persist controlling for the interaction of broadband availability and the unemployment rate (Table 11 in the Online Appendix). This result suggests that internet-facilitated labor market matching is unlikely to be a driver of the results.¹⁷

Third, to shed further light on how the availability of broadband internet may have affected firm performance by reducing discovery-related search costs, I examine how heterogeneity in the relationship between broadband availability and exit by age may be shaped by chain status. Large chain establishments are likely well known to consumers, regardless of age. Accordingly, although I find evidence in the full sample that broadband availability is particularly beneficial to young firms, this pattern may not hold for large chains if the underlying mechanism reflects awareness-related search costs. I present the results of this analysis in Table A12 in the Online Appendix. Indeed, I find that the positive moderating effect of age on the relationship between broadband availability and establishment exit is present for independent and small chain establishments but that it reverses in direction (although is small in magnitude) for large chains. This result provides suggestive evidence of the importance of discovery-related search costs in this setting as the retailers that benefit the most are young and independent firms that are most likely to lack brand awareness.

Fourth, I consider whether e-commerce exposure plays a role in explaining the documented results. As discussed above, even at the end of the sample period, e-commerce reflected a very small portion of retail sales in the United States (U.S. Census Bureau 2024). However, it is possible that sectors with greater e-commerce exposure may respond differently to broadband availability either because they anticipate greater future threat or because greater e-commerce exposure changes consumer search behavior. Using the U.S. Census E-Stats data, I construct a measure of e-commerce exposure at the SIC4 level defined as the percentage of sales that took place online in 2008.¹⁸ I examine how e-commerce exposure moderates the relationship between broadband availability and exit

(Table A13 in the Online Appendix). In the OLS specification, I find that the interaction between broadband availability and e-commerce exposure is negative, suggesting that broadband is *more* beneficial in sectors with greater e-commerce exposure. Using the IV specification and splitting the sample at the median of e-commerce exposure, I find no meaningful difference in effect estimates across subsamples. These results suggest that e-commerce exposure either does not moderate or potentially amplifies the negative relationship between broadband availability and retailer exit. This is difficult to reconcile with a substitution-based mechanism but may be consistent with a search cost-based mechanism if sectors with greater e-commerce exposure were also those where consumers were increasingly engaging in online search and comparison; however, I caution against overinterpretation given the discrepancy between the OLS and IV results. Heterogeneous results hold controlling for the interaction of broadband availability and e-commerce exposure, suggesting that e-commerce exposure does not account for the establishment-level heterogeneity documented (Table A13 in the Online Appendix).

Finally, I consider how local demographic conditions may moderate the relationship between broadband availability and establishment exit by shaping internet usage. Even when access to a technology is held constant, technology may have different outcomes across markets based on differences in consumer usage and familiarity (Wei et al. 2011). I investigate whether this is the case by examining the effect of broadband availability on retail establishment survival on subsamples of establishments based on local educational attainment and income. As education and income are linked to digital literacy and digital capabilities (Warschauer and Matuchniak 2010, Wei et al. 2011, Pereira et al. 2024), retail establishments located in more-educated or higher-income areas may be more likely to capture the benefits of broadband availability. Indeed, I find that this is the case and that the negative relationship between broadband availability and establishment exit manifests more strongly in localities with above-median income and educational attainment as captured at the start of the sample in both the OLS and IV specifications (Table A14 in the Online Appendix). These results suggest that broadband availability was most beneficial when the local population was more likely to be familiar with the technology and adopt it, highlighting that the development of digital capabilities may be an important prerequisite to unlocking the benefits of digital technologies for firms and markets.

Zip Code-Level Analyses: Exit and Entry

The changes in market conditions facilitated by the emergence of broadband and the increase in information

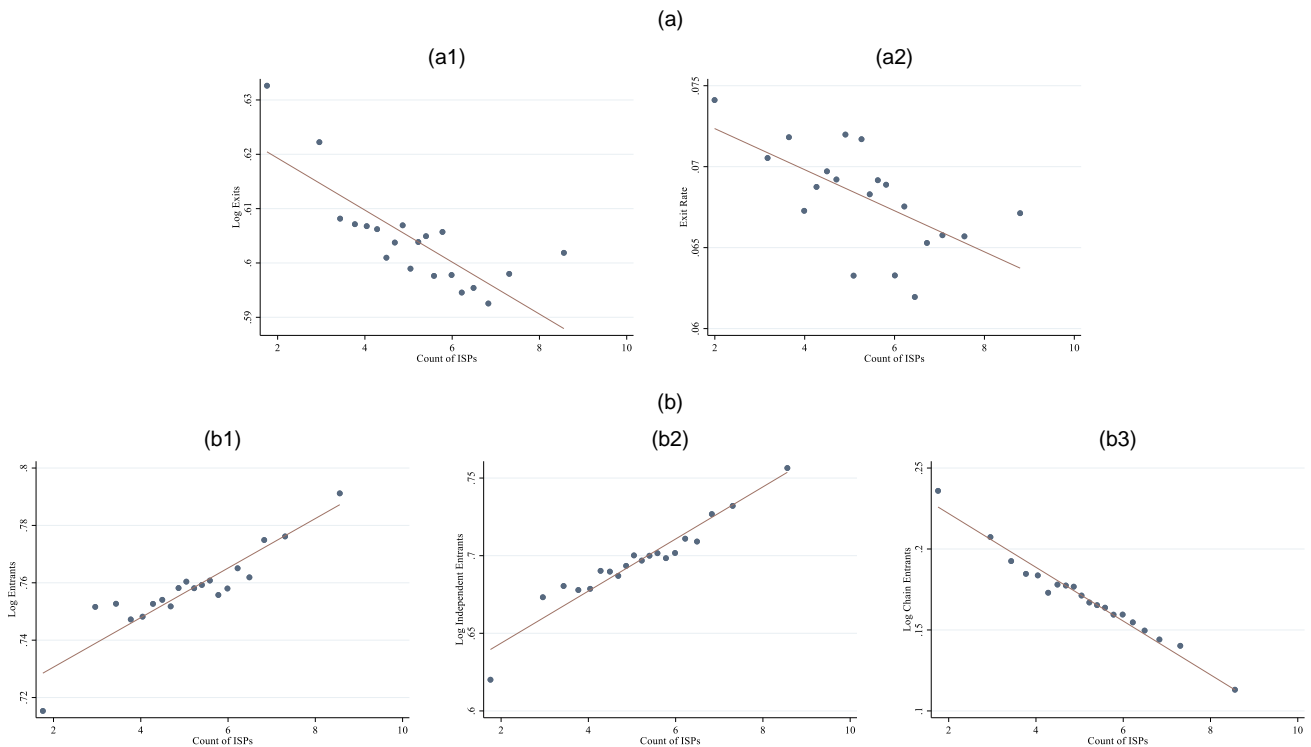
accessibility may be reflected in changing exit and entry patterns at the locality level. I examine this empirically by conducting an analysis at the zip code level that tests whether broadband availability affects the count of exits, the exit rate, and the count of entrants. This analysis serves as a robustness check to the establishment-level results above by examining consistency in the patterns with respect to exit, and it examines whether broadband availability is associated with entry across the entire population and then, among independent establishments versus chain establishments separately. I provide visual evidence of these relationships using binned scatterplots with zip code and year fixed effects in Figure 3. Figure 3 documents preliminary evidence that broadband availability is negatively related to exit (both the count and the exit rate) and positively related to entry. However, breaking down entrants into independent versus chain entrants, broadband availability is positively associated with independent entry and negatively associated with chain entry.

Next, I explore these patterns using regression analyses in Table 5. In line with the establishment-level main results, broadband availability is associated with decreased establishment exit at the zip code level as captured both by the count of exits and by the exit

rate using both the OLS and IV specifications. The OLS estimates suggest that each additional ISP is associated with a 0.5% decrease in the count of exits and a 1.5% decrease in the exit rate, whereas the IV estimates suggest that each additional ISP decreases the count of exits by 3.5% and the exit rate by 13.0%.¹⁹ Further, I find that broadband availability is associated with greater entry by brick-and-mortar retailers and that this increase is driven by independent retailers rather than by chains. The OLS estimates suggest that each additional ISP is associated with a 0.7% increase in the count of entrants and a 1.5% increase in the count of independent entrants but that it is associated with a 1.7% decrease in the count of chain entrants ($p < 0.01$ for all). IV estimates suggest that each additional ISP increases the count of new entrants by 2.9% and the count of independent entrants by 5.1% while decreasing the count of chain entrants by 4.3% ($p < 0.01$ for all). IV estimates are largely consistent using a first-differences specification as used in Kolko (2012) and Chan et al. (2016), except that the model considering exit rate as a dependent variable falls out of statistical significance ($p = 0.125$) (Table A15 in the Online Appendix).²⁰

The results considering entry may be surprising to some. Even with limited threat from e-commerce

Figure 3. (Color online) Broadband Availability and Exit and Entry at the Zip Code Level



Notes. This figure plots binned scatterplots that document the relationship between broadband availability and measures of retailer exit and entry at the zip code level. Estimates are residualized using zip code and year fixed effects. (a) Broadband availability and exit. (a1) Log exits. (a2) Exit rate. (b) Broadband availability and entry. (b1) Log entrants. (b2) Log independent entrants. (b3) Log chain entrants.

Table 5. Estimates of the Effect of Broadband Availability on Zip Code-Level Exit and Entry

Dependent variable	(1) Log <i>exits</i>	(2) <i>Exit rate</i>	(3) Log <i>entrants</i>	(4) Log <i>independent entrants</i>	(5) Log <i>chain entrants</i>
Panel A: OLS specification					
Count ISPs	−0.005*** (0.001)	−0.001*** (0.000)	0.007*** (0.001)	0.015*** (0.001)	−0.017*** (0.001)
Controls?	Yes	Yes	Yes	Yes	Yes
Zip fixed effects?	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes
No. of zips	2,744	2,743	2,744	2,744	2,744
R ²	0.777	0.162	0.815	0.792	0.589
Zip code-year observations	231,197	214,225	231,197	231,197	231,197
Panel B: IV specification					
Count ISPs	−0.036*** (0.006)	−0.009*** (0.002)	0.029*** (0.006)	0.050*** (0.006)	−0.044*** (0.004)
Controls?	Yes	Yes	Yes	Yes	Yes
Zip fixed effects?	Yes	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes	Yes
No. of zips	2,738	2,737	2,738	2,738	2,738
Weak instrument <i>F</i> -statistic	220.6	190.9	220.6	220.6	220.6
Zip code-year observations	226,283	209,835	226,283	226,283	226,283

Notes. The table reports the results of estimating the effect of broadband availability on measures capturing exit and entry at the zip code level. Panel A is estimated using ordinary least squares specifications. Panel B is estimated using instrumental variables specifications. All models control for the log-transformed local average income, unemployment rate, log-transformed population, and percentage change in the housing price index. More details about the specifications and variables used in the analysis are provided in the text. Standard errors clustered at the county level are shown in parentheses underneath the coefficient estimates.

***Statistical significance at the 1% level.

competition during the sample period, if agents are forward looking, one may expect entry to decrease as the specter of e-commerce looms in the future. One possible explanation is that the salience of e-commerce during this period was growing across the country such that local broadband availability was unlikely to meaningfully influence whether and to what extent an entrepreneur feared competition from e-commerce. Alternatively, this result may highlight that broadband availability spurred other changes in entrepreneur behavior. For example, independent retailers may have chosen to enter as they recognized that the new information channel allowed them to reach new customers. Further, broadband access may have lowered entrepreneurs' search costs, allowing them to find higher-quality resources, promising opportunities, and/or underserved markets. As noted, my ability to test mechanisms related to firms' strategic choices is limited based on data availability. However, despite these limitations, these findings provide further evidence that broadband internet availability increased opportunities for small and independent retail establishments.

Robustness

I test the robustness of the results to a number of alternative specification choices: Cox proportional hazard models (Table B1 in the Online Appendix), county-

level measurement of broadband availability (Table B2 in the Online Appendix), log transforming of the independent variable (Table B3 in the Online Appendix), using a log-transformed version of county-level broadband availability (Table B4 in the Online Appendix), and lagging the independent variable (Table B5 in the Online Appendix). There is some variation in the main effect of broadband availability; in particular, it loses statistical power or changes direction in the specifications that log transform the independent variable. Further, the moderating effect of walkability is significant and positive in the hazard model specification. However, all other results are consistent with the main analyses. I use the nonlog-transformed version of the independent variable in the main analysis as it does not exhibit a large amount of skew. I further believe that the estimate of a negative relationship between broadband availability and exit is robust as I consistently estimate a negative relationship between broadband availability and exit in variations of the IV analysis that use a logged slope instrument, use an instrument for broadband availability using an interaction of slope terrain with a categorical year variable, measure broadband availability at the county level (with or without log transformation), or use a lagged measure of broadband availability (Table B6 in the Online Appendix). Finally, I show that broadband availability has a positive relationship with sales and

employment as reported in the NETS data, even accounting for imputed observations (Table B7 in the Online Appendix).

Discussion

In this paper, I study how the emergence of broadband internet affected the basis of competitive advantage for U.S. brick-and-mortar retailers. During this period, when the threat of substitution from e-commerce channels was low, I find that local broadband availability decreased the likelihood of retail establishment exit and that the benefits of broadband availability disproportionately flowed to establishments that faced higher discovery-related search costs *ex ante* because of establishment or market characteristics. The results are consistent with the interpretation that online information availability heterogeneously affected offline performance by decreasing the costs associated with discovery, thus revaluing retailers' endowments and altering the distribution of competitive advantage.

This research provides insight into how an increase in information availability can affect offline competition within an industry, thus extending work that studies how market frictions affect competitive dynamics (e.g., Chatain and Zemsky 2011, Rhodes and Zhou 2019). I show that the emergence of a decentralized information channel altered which firms were best positioned to compete by revaluing establishment endowments and that this revaluation was contingent on the environment that the establishment operated in. Practically, the findings suggest that small businesses competing in offline markets should embrace decentralized information channels, particularly when operating in information-dense environments. Adding to work that suggests that digital distribution channels stimulate "long-tail" effects (e.g., Brynjolfsson et al. 2011), this research shows that online information can help small and niche offerings even in offline settings. By documenting the effect of the availability of a digital information channel on firms operating with a brick-and-mortar business model, this work contributes to literature that studies how firms manage the online-offline interface (e.g., Forman et al. 2009, Raj and Eggers 2022).

The analysis is centered on understanding how the increase in low-cost, decentralized information accessibility facilitated by the emergence of broadband internet can reshape offline competition. The findings are likely to generalize to industry change that similarly increases information availability and decreases the cost of consumer learning about local establishments in a decentralized and low-cost manner without simultaneously altering transaction or production costs. Analogous in the past may have included the Yellow Pages;

online information intermediaries, such as Google Reviews or Google Maps; or mobile internet access, which offered new ways for consumers to learn about establishments operating around them and reduced the cost of discovery without changing the nature of consumption. As digital technologies continue to expand access to information (e.g., Adner et al. 2019, Lanzolla et al. 2020), the results inform when and where offline business are likely to benefit from future digital innovations. For example, future tools, like metaverse platforms or AI-enabled search engines, may generate similar effects to those documented in this paper if they reduce consumer discovery frictions without simultaneously altering transaction or fulfillment models. Importantly, as only 35% of the population in developing markets currently has internet access (Broom 2023, Johnson 2024), the findings provide useful and timely takeaways for firms currently competing offline in such markets as they navigate the early stages of digital infrastructure rollout.

The results may be less likely to generalize to settings where physical transaction costs are changed as well (e.g., the emergence of e-commerce or digital goods). In such cases, firms may need to reconfigure production, fulfillment, or distribution models, making it difficult to know how the search cost mechanism would manifest amidst these other changes. Further, it is unclear whether they would generalize to establishments selling experience goods, where quality cannot be learned *ex ante* (e.g., restaurants). For such goods, given the uncertainty inherent in quality, it is possible that consumers with more information may move toward reliable and tested options rather than opting for unfamiliar offerings (see, e.g., Raj and Eggers 2022 and Reshef 2023). Finally, one intriguing facet about the internet as a phenomenon is the relatively decentralized nature of the technology (e.g., Zhang 2009, Ofek et al. 2011). Although internet traffic is often routed through large search engines, such as Google, no single firm controls access, reducing the likelihood that larger or well-endowed companies can asymmetrically benefit from these tools in the ways that they might for offline information intermediaries (Majumdar and Ramaswamy 1995, Hagiu and Jullien 2011). This raises questions about generalizability to digital platforms that also serve to increase information flow and reduce search costs (e.g., Yelp!), where the platform itself may shape visibility through design choices or monetization strategies. In such cases, whether the effects mirror those presented in this paper may depend on how the platform amplifies or reduces existing visibility advantages.

The limitations and boundary conditions of this research offer opportunities for future study. Scholars could probe how different changes in search costs may have different effects or evaluate how generalizable the results are across different kinds of goods.

Further, research may consider the role of complements in shaping the effects of a given technology. It is possible that the effects of the internet may differ across eras depending on the presence of complements that enable different uses of the technology (e.g., e-commerce services, like Amazon Prime). Future research that explores what tools or services were particularly important in shaping the internet's effect will provide greater understanding of the long-term impact of this technology. Further, the results suggest that local education and income may play a role in unlocking the benefits of technologies for firms and markets, raising questions for policymakers regarding how they can ensure that the benefits of new technologies diffuse across localities, populations, and firms. Finally, although I conduct analyses to triangulate the mechanisms underlying the results, I cannot link firm performance to data on firm strategies or consumer behavior. Future studies that link firm performance to consumer behaviors as information channels become available would add richness to the understanding of the mechanisms through which such technologies affect firms. Similarly, future studies could explore whether and how retail establishments chose to engage with this technology (e.g., customer outreach, internet sales channels) to provide greater insight into which strategies are critical to capturing benefits from a reduction in consumer search costs.

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Endnotes

¹ See <https://www.census.gov/library/publications/2010/econ/2008-e-stats.html>.

² A broader literature in economics also finds that broadband has contributed substantially to GDP growth in the United States (Greenstein and McDevitt 2011) and globally (Czernich et al. 2011), and it has been linked to employment growth (Kolko 2012, Nazareno and Jose 2025) and entrepreneurship (Conroy and Low 2022).

³ By 2008, 55% of American adults had broadband internet at home (Horrigan 2008).

⁴ Data limitations prevent me from capturing adoption or availability of dial-up internet connections. Although beyond the scope of the empirical analyses in this paper, I expect that dial-up internet availability may have had similar effects, although muted in magnitude, as the results reflect the effect of information availability.

⁵ I utilize the zip code as the geographic unit of analysis to avoid introducing additional measurement error; however, I find consistent results using a measure of broadband availability at the county level (Table B2 in the Online Appendix).

⁶ I consider the relationship between broadband availability, employment, and sales conditional on employment in later analyses (Table B7 in the Online Appendix).

⁷ I later use additional analyses to rule out explanations related to productivity effects or labor market matching.

⁸ Results are robust to using the nonwinsorized same-industry establishment density.

⁹ Table A1 in the Online Appendix presents a correlation matrix.

¹⁰ In robustness checks, I show that the main and heterogeneous results are consistent using a hazard specification (Table B1 in the Online Appendix).

¹¹ Note that establishment fixed effects are not appropriate in this context as exit is the dependent variable. Accordingly, establishment fixed effects would absorb all variation in the dependent variable for firms that never exit and thus, exclude them from the sample.

¹² I find consistent results using the interaction of the terrain slope and categorical time variables (Table B6 in the Online Appendix); estimates are smaller in magnitude than the baseline IV analysis but larger than the estimates obtained from the endogenous hazard or LPM models. Further, I note that although Hansen's test cannot be used when using the interaction between terrain slope and the linear time trend as the instrument as the first stage is just identified, I believe that the risk of violating the exogeneity assumption is lower with the linear time trend as the simplicity in its temporal structure may be less sensitive to short-term, period-specific shocks that could introduce the potential for correlation with the error term.

¹³ Missing data on slope terrain for a small number of zip codes lead to fewer observations for the IV estimation. This is the case for Table 5 as well. Further, missing data on local and demographic controls lead to fewer observations in column (3) relative to columns (1) and (2) in Table 5 and column (6) relative to columns (4) and (5) in Table 5.

¹⁴ I consider the temporal dynamics underlying the relationship between broadband availability and retailer exit in additional analyses (Figures A1 and A2 and Table A5 in the Online Appendix). I summarize these tests in the Online Appendix but find some evidence that this relationship may manifest in a temporally diffuse way rather than immediately.

¹⁵ This is true regardless of the specification choices made (i.e., what controls or fixed effects are included). Hazard model estimates are similar in magnitude to those obtained by the OLS (Table B1 in the Online Appendix).

¹⁶ Even with the split-sample approach, in some specifications, the first stage is weak (<10).

¹⁷ Online job boards and hiring resources were also predominantly used for hiring in high-tech and high-skill jobs and by larger firms during this period (McMillan 2000, Hansell 2002) rather than the retailers in our sample.

¹⁸ Values are low for all sample establishments, ranging from 0.03% for general merchandise stores up to 2.35% for music stores, which highlights the limited role of e-commerce during this time period. For furniture stores, the latest data point present in the data before sample end is from 2006, so I use this value.

¹⁹ Effect sizes for the logged dependent variables are calculated as $e^{\beta} - 1$. Effect sizes for nonlogged dependent variables are constructed by dividing the coefficient by the sample mean.

²⁰ Such a specification is not well suited for the establishment-level analysis, which uses exit as a dependent variable and features an unbalanced panel as establishments enter and exit at different time points. First differencing would both eliminate meaningful variation and introduce sample selection concerns.

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