The Impact of Distance in Retail Markets

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The past two decades have witnessed the growth of e-commerce from $27.6 bn in U.S. revenue in 2000 to $870.8 bn in 2020, or 13.2% of total U.S. retail spending. A large share of this growth comes from the largest online retailer, Amazon.com, which accounts for 24.9% of 2020 e-commerce revenue. Over this period, Amazon – and other online retailers – has invested heavily in logistics networks, growing fulfillment centers from six to 234 facilities and, more recently, rapidly integrating into sortation and last-mile delivery. Notably, Amazon handles about 20% of all U.S. package deliveries in 2020.[1]

In Houde, Newberry and Seim (2023), we quantify the trade-offs behind Amazon's distribution expansion through 2018. A denser distribution network reduces the company's shipping cost by placing fulfillment centers closer to consumers and generating cost savings from expansion into package sortation. At the same time, densification drives up facility fixed costs and reduces scale economies from order processing. Prior to 2017, an expansion of distribution into new states also exposed the company's consumers to new sales tax under Nexus tax laws, limiting revenue gains. We abstracted from other demand-side effects of Amazon's logistics investments that we revisit here. The company's more recent expansion into last-mile delivery has allowed it to improve the consumer's delivery experience in two distinct ways. First, Amazon now targets an on-time delivery rate of 97%, significantly above e-commerce averages. Second, Amazon has rolled out same-day delivery, which it offers to approximately 50% of the population in 2020.[2]

In this paper, we quantify the implications of this improved delivery convenience for consumers' online shopping behavior and offline store visits. We exploit the staggered roll-out of Amazon's network to quantify the impact of local network proximity and same-day availability on two measures of demand: online transactions from Amazon, which we obtain from the comScore Web Behavior database, and offline retailer foot traffic from SafeGraph.

During the first wave of Amazon's investments, despite large declines in consumer distance to the fulfillment network, we do not find any significant impact of distance to Fulfillment Centers (FC) on demand. We confirm, however, earlier results of sizable reductions in demand due to exposure to sales tax.[3] More recently, we do find that same-day service availability facilitated by last-mile investments not only increases Amazon's demand, particularly in zip codes served by a dense last-mile network, but also leads to a pronounced drop in the number of visits to big-box retailers, our off-line demand proxy.

The rest of the paper is organized as follows. Section I introduces the main data sources and summarizes the expansion of Amazon's logistics network, Section II presents the empirical analysis, and Section III concludes.

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[1] See https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf and https://qz.com/2078328/amazon-now-delivers-more-us-packages-than-fedex.

[2] See https://sellercentral.amazon.com/forums/t/on-time-delivery-penalty/1448160/2; own calculations.

[3] See Baugh, Ben-David and Park (2018), Einav, Levin and Sundaresan (2014), and Houde, Newberry and Seim (2023).

I. Data and stylized facts

We rely on two primary data sources. For online purchase behavior, we utilize data over the period from 2006 to 2019 from comScore's Web Behavior Database, which records households' online browsing and purchasing activity. We focus on individual transactions, of which we observe 1.55 million from 286,365 households, and consider, as a proxy for demand, whether the household purchases from Amazon. Amazon is the seller for 39.52% of transactions.

We further rely on mobile phone location data from SafeGraph over 2018-2021 to construct the monthly number of visits per registered device from each zip code to the location of a big-box retailer.[4] On average, we observe 0.35 and 0.34 big-box visits per device in a zip code with and without same-day availability, respectively, derived from an average of 1,595 and 503 registered devices.

We supplement these data with demographics from the Census, detailed sales tax rates from TDS Data Systems, and Amazon's sales tax collection obligations in each state from Baugh, Ben-David and Park (2018).

We derive distribution network information and calculate the straight-line distance between Amazon's various facilities and consumer zip code locations using facility data obtained from MWPVL over 2000-2021. We focus on three types of facilities: (1) Fulfillment centers, or warehouses, where we assume that the closest facility to the consumer fulfills their order; (2) sortation centers, where packages are divided into delivery zones, and (3) last-mile delivery centers that handle the final package delivery to the consumer. Amazon offers same-day delivery to some of its consumers; we record the service's availability in each zip code from monthly snapshots of Amazon's site on archive.org over 2017-2021 and for Combined Statistical Areas (CSAs), our markets, from press releases.

[4]This includes Big Lots, Costco, Dollar General, Dollar Tree, Family Dollar Stores, Walmart, Sam's Club, and Kmart.

Table 1 summarizes the expansion of Amazon's distribution network from 2010 onwards. The company opened the first last-mile delivery center in 2010, at a similar time as its entry into package sortation. In terms of facility count, markets with same-day service, and within market access to last-mile facilities, however, the table shows that the roll out of its last-mile delivery network began in earnest in 2016. By 2020, the company offers same-day service in 42 CSAs, reaching 86% of the U.S. population. Most CSAs are only partially covered; by 2020, 66% of the markets' population is within 25 miles of a last-mile center and 60% receive same-day service. Figures A1 and A2 in the Online Appendix illustrate the spatial roll-out of the fulfillment and last-mile delivery center networks; the figures highlight the sharp declines in distance to a fulfillment center over time from 344 miles in 2000 to 71 miles in 2020.

II. Empirical Analysis

A. *Fulfillment network investment*

We begin by measuring the impact of fulfillment network density on demand. We exploit the roll-out of Amazon's fulfillment center network and the more recent expansion into sortation between 2006 and 2015. During this period, Amazon charged sales tax only in states with a physical presence and, until approximately 2010, commonly negotiated delays between the opening of a distribution facility in a new state and the onset of this tax liability. The timing of investment and tax changes therefore gives us to independent variation in taxes and network density that we rely on to identify the effect of proximity to a fulfillment facility and taxes on the propensity to buy from Amazon.

We measure proximity in terms of both distance to the nearest fulfillment center and distance-weighted fulfillment capacity.[5]

[5]In the Online Appendix, we report additional results using data from the USPS on the estimated shipping speed between the consumer and facility zip code locations, as well as measures of proximity to sortation facilities.

Table 1—: Expansion of the distribution and logistics network, 2010-2020

	2010	2012	2014	2016	2018	2020
Facilities						
Fulfillment Center (FC)	17	31	57	74	128	234
Sortation Center (SC)	0	1	12	27	35	67
Last Mile Center (LM)	1	1	10	47	116	388
States with 1+ facilities	9	11	18	29	37	40
Proximity						
FC Distance (m)	254.20	185.17	148.46	124.79	87.98	70.59
% Pop with SC	0.02	0.02	0.35	0.77	0.87	0.88
Same-Day (S-D) Rollout						
Markets	6	6	11	22	31	42
% Pop in Markets	0.17	0.17	0.31	0.40	0.81	0.86
% Market Pop with LM	0.03	0.03	0.34	0.73	0.57	0.66
% Market Pop with S-D					0.48	0.60

Notes: Under proximity, FC distance is the population-weighted average distance between each zip code and the closest fulfillment center. % Pop with SC denotes the population share with a sortation center within 150 miles. Under same-day roll-out, markets and % Pop in Markets denote the number of CSAs with availability and the markets' share of the US population, respectively; while % Market Pop with LM and with S-D measure the percent of the markets' population with a last-mile facility within 25 miles and with same-day availability.

We rely on the comScore data to define our main dependent variables, indicators of the household's choice of Amazon.com or a competing retailer with an existing physical presence (e.g. Walmart.com or Target.com) for a given order.

The results of four linear probability models are presented in Table 2. Regardless of measure, we find a precise zero effect of proximity to the fulfillment network on either the demand for Amazon or its closest substitutes. This result is robust across alternative measures of distances presented in the Online Appendix.

We separately estimate the effect of taxes on demand, exploiting primarily the discrete change in tax status following Amazon's entry into a new state for identification. All specifications show a robust negative effect of taxes on online orders from Amazon: moving from no tax to the average of 6.3% is associated with a 1.5pp decrease in the likelihood of ordering from Amazon (or 5% of the average), but a 1.7pp increase in the probability of ordering from another taxable online retailer. Thus, the expansion of the fulfillment network into new states lowers demand significantly, which we explore further in Houde, Newberry and Seim (2023).

In summary, we find that locating fulfillment facilities close to consumers has no effect on local demand, even though network density may impact the average delivery speed for all consumers. Proximity to a fulfillment facility may thus not be a necessary condition for expedited delivery: from 2005 to mid-2015, Amazon offered their best shipping terms, free two-day shipping, to *all* Prime members, regardless of location. Similarly, FedEx and UPS offer overnight shipping to any U.S. location, albeit at a steep premium.

B. Last-mile investment and same-day shipping

So far, we have established that Amazon's investments in fulfillment capacity do not have a direct effect on demand. Here, we analyze the effect of Amazon's last-mile investments, allowing it to deliver goods directly to consumers and to offer "same-day" delivery to specific zip codes. Those consumer-facing investments directly affect the convenience of Amazon's services and hence, potentially, demand. Using data from comScore, we first measure the relationship between the probability of buying at Amazon.com, relative to other online platforms, and last-mile investments. Then

Table 2—: Effect of fulfillment network investments and taxes on online orders

	(1)	(2)	(3)	(4)
Log(1+tax)	-0.242	0.296	-0.256	0.311
	(0.102)	(0.099)	(0.101)	(0.098)
Log(FC Dist)	0.001	-0.001		
	(0.003)	(0.003)		
Log(Dist Weighted Size)			0.008	-0.008
			(0.007)	(0.006)
Observations	455,340	455,340	455,340	455,340
r-Sq	0.16	0.10	0.16	0.10
DV Mean	0.30	0.37	0.30	0.37
Retailer group	Amazon	Taxable online	Amazon	Taxable online
Sample	2006-2015	2006-2015	2006-2015	2006-2015
Zip Codes	7140	7140	7140	7140

Notes: Additional controls: Zip-code FE, Census division x Month-year FE, and household demographic characteristics. Robust standard errors in parentheses (cluster=county).

we use data from SafeGraph to measure the effect of last-mile investments on shopping trips.

We restrict the sample to zip codes in CSAs with a population above 500,000. We control for zip code and census-division by time period fixed effects. We thus identify the effect of same-day delivery from zip codes that gained access between 2018 and 2019. Similarly, we exploit the staggered roll-out of last-mile facilities to identify the effect of proximity to the last-mile network. Between 2018 and 2019, the faction of zip codes with same-day availability increased from 37% to 46.6%, while the number of last-mile facilities within 25 miles increased from 1.28 to 1.75 on average and to 2.52 for zip codes with same-day access in 2019, consistent with the importance of last-mile investments for increased delivery speed.

Table 3 presents the results. The first three columns use data on online transactions. The comScore data is relatively sparse, covering only approximately 50% of zip codes in the selected markets. The dependent variable equals to one if the merchant is Amazon.com, and zero otherwise. Column (3) is our main specification. We find that availability of same-day shipping increases the share of Amazon orders, especially for zip codes located in close proximity to multiple last-mile facilities: the effect of same-day availability ranges from 1 to 7 percentage points for zip codes near three or more facilities (relative to a base propensity of buying from Amazon of 55%).

The last three columns of Table 3 repeat the same exercise using data on the average monthly number of trips to big-box stores. Again, our main specification (6) shows that the effect of same-day delivery on shopping trips is negative, but only in zip codes located close to multiple facilities. In particular, access to same-day shipping is associated with 8% fewer shopping trips per month for zip codes located near 3 last-mile facilities.

In summary, we find strong evidence that last-mile investments allowed the company to offer same-day shipping to a growing number of urban households. This in turn increased demand for Amazon and significantly reduced visits to big-box retailers. Interestingly, last-mile network density alone or the availability of same-day shipping without access to a dense last-mile network have no effect on zip code demand. We interpret this result as evidence that the two investments are complementary. For instance, our results are consistent with the idea that the number of delivery facilities determines the variety of goods eligible for same-day delivery. Increasing the density of last-mile facilities in areas with same-day access, therefore, increases the willingness-to-pay of consumers for same-day shipping,

Table 3—: Effect of last-mile investments on Amazon's demand

	1(Amazon.com order)			Avg. big-box store trips (log)		
	(1)	(2)	(3)	(4)	(5)	(6)
Same-day (Zip)	-0.010		-0.047	-0.036		0.025
	(0.016)		(0.023)	(0.014)		(0.026)
Same-day (CSA)	0.042	0.035	0.048	0.031	0.011	0.023
	(0.020)	(0.015)	(0.020)	(0.010)	(0.010)	(0.011)
Same-day (Zip) x LM			0.020			-0.035
			(0.008)			(0.012)
LM Facilities (25 m.)		-0.001	-0.017		-0.034	-0.008
		(0.009)	(0.012)		(0.013)	(0.010)
Observations	166,114	166,114	166,114	174,830	174,830	174,830

Notes: Additional controls: Zip-code FE, Census div x Month-year FE. Robust standard errors in parentheses (cluster=county).

and ultimately allows the platform to compete directly with traditional big-box retailers.

III. Conclusion

The growth of e-commerce has sparked the interest of economists and regulators alike. Our results point to increases in consumer willingness to pay for the improved delivery service, and economies of density in the fulfillment of orders (consistent with the modeling in Houde, Newberry and Seim (2023)). We thus provide further evidence on the sources of consumer welfare gains from e-commerce (Dolfen et al. 2022). Our results also suggest that Amazon's last-mile delivery investments have intensified online-offline substitution in ways that may significantly change the urban landscape of the retail sector (Cao et al. 2022), similar to the earlier rise of big-box retail (Basker 2007). Lastly, Amazon's outsized role in the growth of e-commerce has raised concerns about anti-competitive behavior (Gutierrez 2022). Consumer valuation of delivery convenience and the scale benefits of Amazon's logistic network have nuanced implications for the pricing of the company's order fulfillment services that many third-party sellers use and thus the company's broader platform strategy. We leave the quantification of these effects to future research.

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