The Market for High-Quality Medicine: Retail Chain Entry and Drug Quality in India

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A Online Appendix

A.1 Indian Pharmacopeia Compliance

Samples of ciprofloxacin and amoxicillin must meet three requirements in order to comply with the Indian Pharmacopeia (IP) quality standard. The active ingredient concentration of the samples must be within 90-110 percent of the labeled dosage. Dissolution indicates the percent of the sample's active content that dissolves into a known medium within a predetermined time, and must exceed 80 percent for the sample to comply. To measure uniformity of weight, the analyst weighs 30 individual tablets. The uniformity parameter is a function of both the minimum and the maximum absolute deviation in weight within the sample, and must be less than 5 for amoxicillin and less than 7.5 for ciprofloxacin. The measurement error for each continuous quality test depends on the number tablets in the sample. Our mystery shopper audit includes 30 tablets, which leads to measurement error of 1-2 percent in each continuous quality outcome, according to the laboratory. The error rate for pharmacopeia compliance is even lower because most samples are not marginal for compliance. Laboratory-based quality measurement is more informative than Raman spectroscopy, which only indicates whether a sample is authentic. Appendix Figure 1 shows the frequency distributions for these quality components, pooling samples of ciprofloxacin and amoxicillin from all sample manufacturers.

Appendix Table 1 shows the impact of chain entry on these quality components for the full sample (Panel A) and the sample from non-national manufacturers (Panel B).[1] Columns 1-3 report results for active ingredient concentration. The quantity of active ingredient declines by 6.86 mg in control markets and by 3.33 mg in treatment markets, leading to a (statistically insignificant) treatment effect estimate of 3.53 mg in Column 1.[2] Because quality is non-monotone for active ingredient concentration, and is optimized at the labeled dosage, Column 2 reports the effect on the absolute percent deviation from the labeled dosage. This estimate is pronounced and statistically significant for non-national drugs. Column 3 shows that chain entry increases the probability of compliance with the active ingredient requirement by 4.2 percentage points overall and by 18 percentage points for non-national drugs.

The rest of the table shows the impact on dissolution and uniformity of weight. Columns 4 and 5 report the effects of chain entry on dissolution. Dissolution improves in treatment markets while it remains constant or declines slightly in control markets, leading to a significant effect on this dimension of pharmacopeia compliance. We find no effect of chain entry

[1]Figures 4A and 4B in the paper show the effects on active ingredient concentration and dissolution graphically.

[2]Column 1 excludes seven observations with a labeled dosage of 250 mg. Pharmacists provided these samples as substitutes for the 500 mg samples the auditors requested. Normalizing the dosage to 100 percent and including these observations does not affect the estimate.

on uniformity of weight. Low values indicate greater uniformity, which equates to higher quality. Columns 6 and 7 show that average uniformity rises between the survey rounds, but pharmacopeia compliance is unchanged in both treatment and control markets.

A.2 Weather Variation and Drug Quality

As we discuss in Section 4.3 of the paper, more extreme weather conditions may explain the decline in drug quality from Round 1 to Round 2. We obtained daily peak temperature and humidity readings for Hyderabad from the National Oceanographic and Atmospheric Administration (NOAA) website. For pharmacy audit days, the daily peak relative humidity rose by 6.5 percentage points while the daily peak temperature fell by 1.1 degrees from 2010 to 2011. The humidity difference is statistically significant while the temperature difference is not. However the percent of days with "dangerous conditions" rose from 52 percent to 97 percent from 2010 to 2011.

Appendix Figure 2 illustrates this difference by plotting peak relative humidity and temperature levels by round. The red box indicates dangerous temperature and humidity combinations. Note that temperature and relative humidity are mechanically negatively correlated because warmer air can hold more moisture and that some data points overlap in the figure. The figure illustrates that while some days fall below the "dangerous" threshold in Round 1, nearly all days fall above the threshold in Round 2.

A.3 The Geography of Sample Markets

Appendix Figure 3 shows the locations all 20 markets within Hyderabad. The average distance to the city center is 13.0 km for treatment markets and 9.6 km for control markets, which not statistically different ($p = 0.19$). Moreover, the city center of Hyderabad is not necessarily a meaningful economic reference point because the metropolitan area also includes the twin city of Secunderabad to the north. The comparison of treatment and control markets in Table 1 provides a better indication of market demand.

Panel A of Appendix Table 2 assesses the robustness to distance heterogeneity in two ways. Odd columns repeat the quality and price regressions from Tables 4 and 5 in the paper but control for the interaction between Post and distance to the city center. Both quality and price estimates resemble the main estimates in the paper, which suggests that distance heterogeneity does not contribute to our results. Even columns limit the sample to candidate markets that have similar distances by dropping the five markets closest to the center. Quality results closely resemble baseline estimates while price results are similar but smaller.

A.4 Traffic Growth After Including the Chain Pharmacy

The discussion of traffic growth in Section 5.2 excludes the chain in order to focus on the impact for incumbents. As another test of the identifying assumption, we include chain traffic in order to compare total traffic growth in treatment and control markets. This exercise is not straightforward for several reasons. We only observe traffic for a subset of each market's pharmacies, which creates measurement error for market-wide traffic estimates. Secondly, our consumer survey indicates that chain shoppers purchase 25 percent more medicine by volume than incumbent shoppers.

Nevertheless, we examine traffic growth by treatment status, and find that traffic growth is slightly lower but insignificantly different in treatment markets once we include traffic at the chain. Traffic in treatment markets is 3 percent lower in Round 1 ($p = 0.75$), 12 percent lower in Round 2 ($p = 0.15$), and 8 percent lower in Round 3 ($p = 0.40$). We account for heterogeneity across stores in the quantity per customer using estimates from our consumer survey. Scaling customer traffic by the average quantity per customer does not change these estimates but cause the differences by treatment status to become highly insignificant ($p > 0.5$).

Panel B of Appendix Table 2 explores whether unobservables correlated with traffic growth confound our estimates. As above, odd columns control for the interaction between $Post_t$ and market-wide traffic growth. If growth in customer traffic is correlated with unobservable determinants of quality and price, this approach should change the treatment effect estimates. However estimates closely resemble the baseline results in Tables 4 and 5. Even columns restrict the sample to 14 markets for which traffic growth is comparable across treatment and control markets.[3] There is no difference in average traffic growth across treatment and control markets under this restriction. The table shows that quality results closely resemble our baseline estimates. Price results are weaker but are qualitatively similar to our main findings. These results suggest that unobservables correlated with traffic growth do not confound our results.

A.5 Estimates for Only the 18 Candidate Entry Markets

This subsection explores three potential differences between treatment and control markets. First, our sample includes two control markets that were not candidate entry markets. Consumers in these markets have lower socioeconomic status, with 23 percent lower household income and 1.7 fewer years of schooling ($p < 0.01$ for both variables). We include these markets in our baseline estimates to improve precision. Appendix Table 3 reproduces our main results while excluding these markets. Quality results appear in Columns 1 through 4 and price results appear in Columns 5 through 8. We report all estimates with and without demographic and economic controls. Point estimates closely resemble the baseline estimates in Tables 4 and 5, however standard errors are around 15 percent larger. The similarity of these results indicates that our findings are not sensitive to whether these markets are included.

A.6 Robustness to Unobservable Trends

Appendix Table 4 explores the robustness of our results by controlling for the interaction of *Post* and three sets of baseline observable characteristics, including market demographic characteristics, market health characteristics, and pharmacy characteristics. We describe the demographic and health variables above. Pharmacy characteristics include customer

[3]We restrict the sample to markets for which the change in traffic from Round 1 to Round 2 ranges from -61 to 85, which excludes several high-growth control markets.

traffic, establishment age, signage, and space allocated to medicine. In Columns 1-3, the effect on drug quality remains statistically significant and varies from 0.14 to 0.22, compared to the estimate of 0.20 in Table 4 of the paper. In Columns 5-7, the effect on log price is also significant (except for Column 7) and ranges from -0.10 to -0.20, compared to -0.11 in Table 5 of the paper. The proportional selection δ is generally either large or negative in all specifications, which indicates that the effect of unobservables confounds must be larger than (or negatively correlated with) the effect of observed variables driving the treatment effect. Only in one specification, in column 2, is the δ positive and less than one.

Our results may arise because of mean reversion if the chain enters markets where quality is unexpectedly low or price is unexpectedly high. We investigate this possibility by interacting $Post_t$ with the baseline value of the dependent variable (averaged by pharmacy) in Columns 4 and 8 of Appendix Table 4. These controls do not affect the magnitude or significance of our estimates.

A.7 Treatment Spillovers

This subsection discusses the possibility that chain entry could indirectly affect prices and quality in control markets. We proxy for markets spatially using the area within a 0.5 kilometer radius from the candidate entry site. Markets do not overlap or share borders. For control markets, the closest treatment market is an average of 8.1 kilometers away and a minimum of 2.4 kilometers away, suggesting that spillovers are unlikely. More formally, Appendix Table 5 tests whether results are sensitive to the proximity of treatment and control markets by excluding nearby control markets from the analysis. Odd columns exclude four control markets that are within 5 kilometers of a treatment market while even columns exclude eight control markets that are within 10 kilometers of a treatment market. The remaining control markets are an average of 10 kilometers away from a treatment market under the first restriction and 12 kilometers away under the second restriction. Estimates in the table closely resemble our baseline estimates, suggesting that treatment spillovers do not confound our results.

A.8 Changes over Time for Non-National Brands

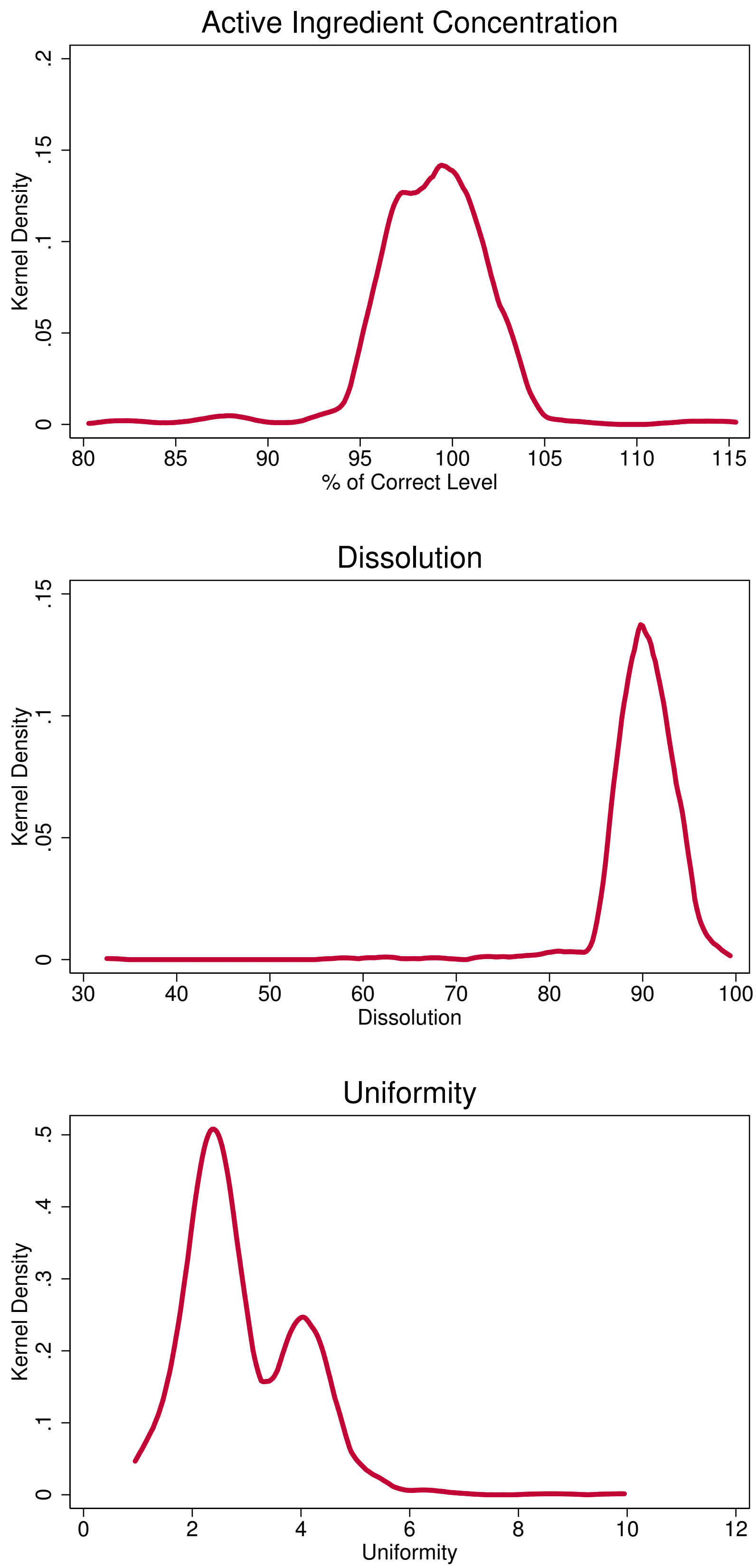
Treatment effect estimates for non-national brands are identified through changes over time in quality and price within this subsample. To clarify this source of variation, Appendix Figure 4 reproduces the plots in Figure 3 of the paper for non-national manufacturers. Pharmacopeia compliance is initially 5 percentage points higher in control markets ($p = 0.22$). The non-national treatment effect estimate of 0.20 (Column 5 of Table 4) is based on a 5 percentage point quality improvement in treatment markets over time and a 15 percentage point deterioration in control markets. As we discuss previously, the secular decline in quality is most likely caused by the marked increased in both humidity and temperature during the second survey round. Prices are initially 8.4 percent higher in treatment markets ($p = 0.09$). The 12 percent price decline (Column 5 of Table 5) is based on a 5 percent increase in control markets and a 7 percent decrease in treatment markets.

A.9 Mechanisms

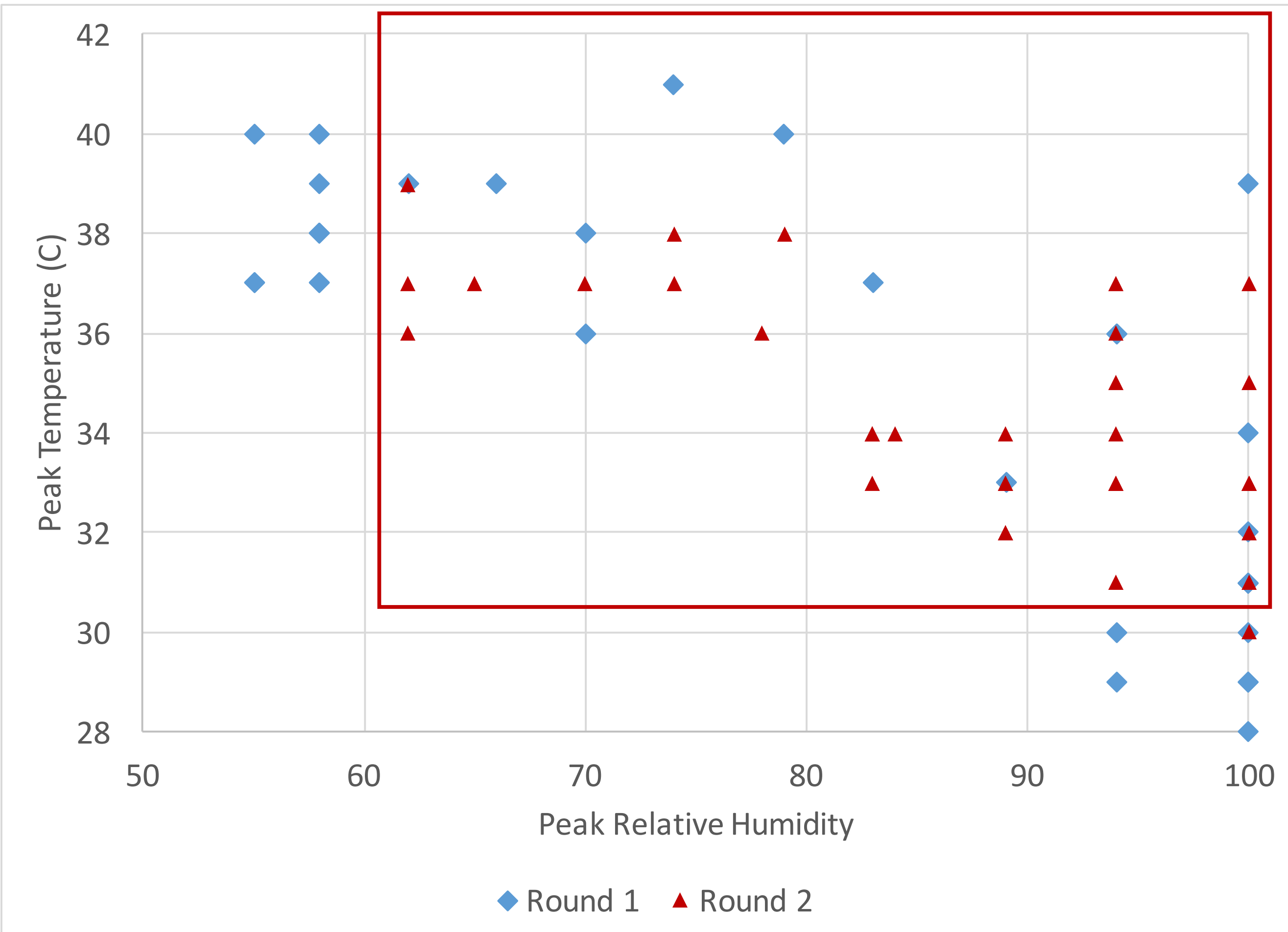
This subsection discusses alternative ways that chain entry could influence drug quality and prices for incumbents. Chain entry could affect incumbent quality via the wholesale market. By purchasing directly from manufacturers, the chain reduces the wholesale demand for medicine. However, our results are unlikely to arise through this channel because the wholesale market spans the city and is geographically diffuse. Any impact on wholesale demand is localized in treatment markets, which are a very small subset of all markets in the city. The seven new chain stores represent less than three percent of MedPlus stores, and less than 0.2 percent of pharmacies in the city

Chain entry could directly increase the demand for high-quality medicine by shifting consumer perceptions or quality preferences. In the consumer survey, respondents indicate whether drug quality, store convenience, and store familiarity are important considerations when purchasing medicine. We restrict the sample to non-shopping consumers; the responses of shoppers are more difficult to interpret because these respondents have elected to purchase medicine. Appendix Table 6 shows that chain entry increases the importance that consumers report placing on drug quality, which suggests that the chain increases the preference for high-quality medicine. Chain entry does not increase the perceived importance of other pharmacy characteristics. An increase in demand for high-quality medicine cannot, alone, explain our findings on its own because greater demand should increase prices. The price reductions in Table 5 of the paper suggest that competition over price and quality is the dominant channel.

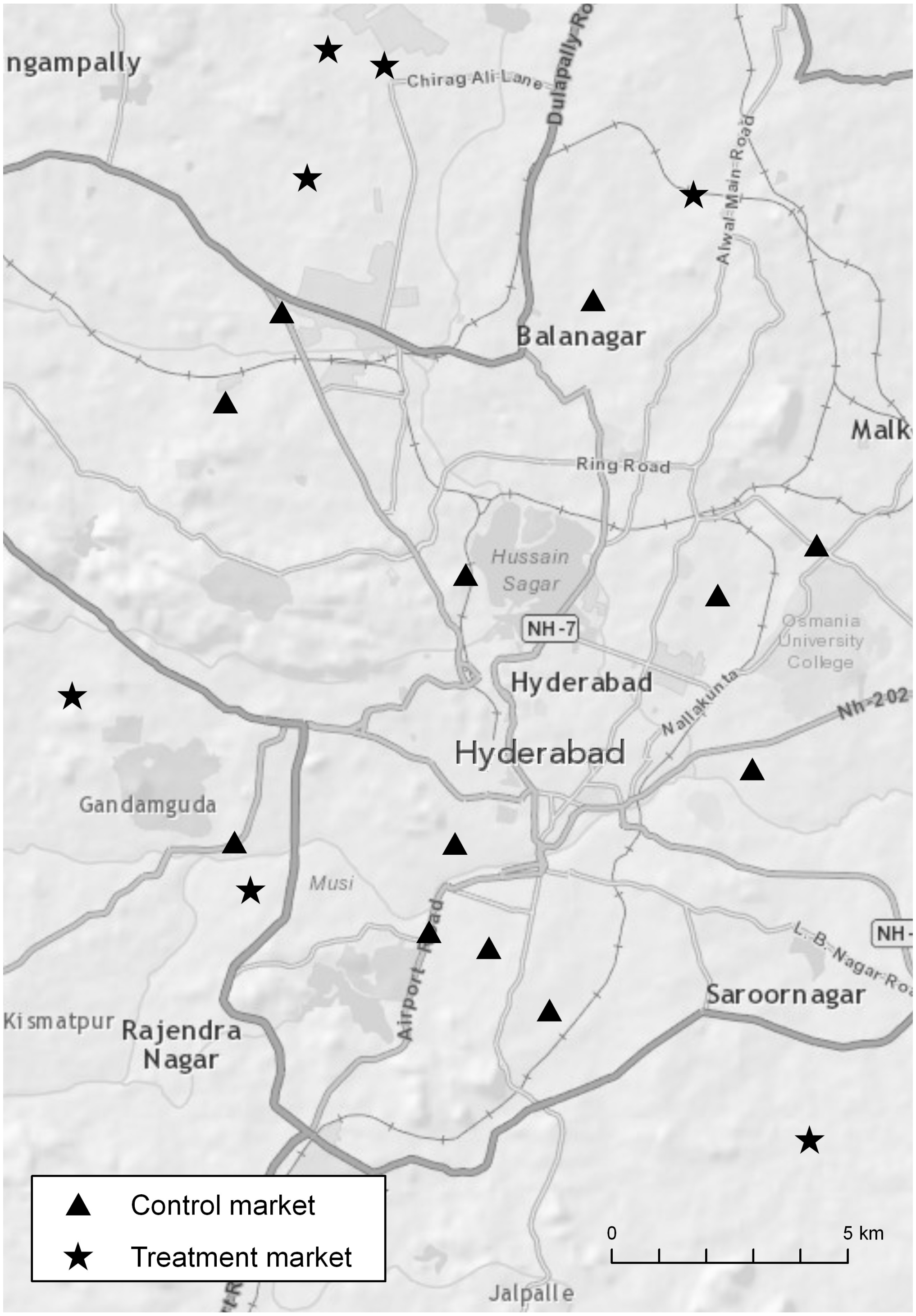
Chain entry may affect incumbent prices or quality by changing the selection of incumbent shoppers. Because the chain offers both higher quality and lower prices, it does not necessarily draw away high-SES or low-SES customers differentially. If it steals high-SES customers, the chain may encourage incumbents to cater to the remaining low-SES customers through lower prices and quality. Because both quality preferences and drug demand are positively correlated with SES, customer selection cannot explain why chain entry has different effects on quality and prices. We investigate the role of selection further by regressing the demographic characteristics of incumbent customers on chain entry in Appendix Table 7. With estimates that are small and statistically insignificant, the table shows no effects of chain entry on shopper characteristics. These results cast doubt on selection-based explanations for the price and quality effects of chain entry.



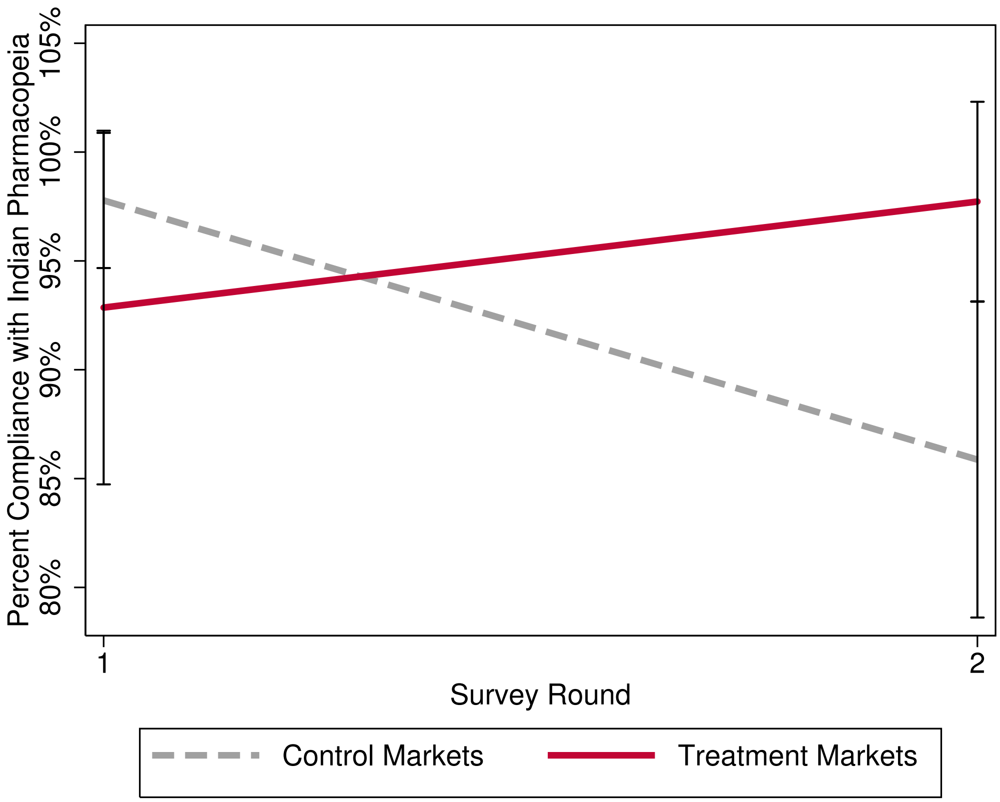
Appendix Figure 1: The Distribution of Quality Components

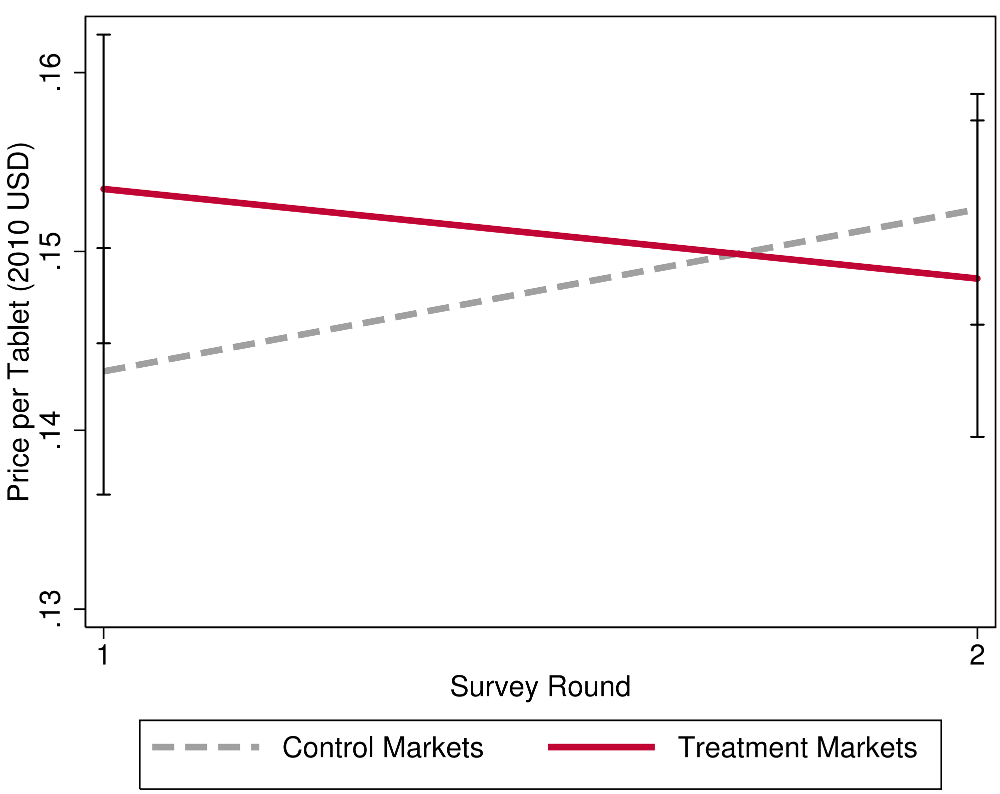


Appendix Figure 2: Extreme Heat and Humidity During Data Collection, by Round



Appendix Figure 3: The Location of Sample Markets in Hyderabad





Appendix Figure 4: Quality and Price Changes for Non-National Drug Samples

Appendix Table 1: The Impact on Quality Components

Quality Component:	Active Ingredient Concentration			Dissolution		Uniformity	
Dependent variable:	Raw	Abs. % Dev.	Pass	Raw	Pass	Raw	Pass
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: All Manufacturers							
Post entry	-6.86***	0.018	-0.018	0.11	-0.024*	-0.50***	-0.020**
	(1.37)	(0.28)	(0.016)	(0.50)	(0.013)	(0.081)	(0.0092)
Post entry · entry market	3.53	-0.24	0.042**	1.30	0.032*	-0.11	-0.0036
	(2.45)	(0.37)	(0.019)	(0.89)	(0.015)	(0.18)	(0.014)
Wild bootstrap p-value (post · entry)	0.19	0.53	0.04	0.18	0.05	0.56	0.80
Panel B: Non-National Manufacturers							
Post entry	-9.93**	1.82**	-0.12***	-0.88	-0.054	-0.64***	-0.029
	(3.05)	(0.60)	(0.035)	(1.46)	(0.033)	(0.17)	(0.031)
Post entry · entry market	1.54	-2.52**	0.19***	3.71*	0.11**	-0.033	0.0038
	(5.29)	(0.91)	(0.059)	(1.91)	(0.044)	(0.21)	(0.039)
Wild bootstrap p-value (post · entry)	0.77	0.01	< 0.01	0.06	0.02	0.88	0.91

Note: The table shows the impact of chain entry on the three components of Indian Pharmacopeia compliance. Market-clustered standard errors appear in parentheses. All regressions include market fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 2: Additional Robustness Tests

	Complies with Indian Pharmacopeia				ln(Price per Tablet)			
Manufacturers:	All		Non-National		All		Non-National	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Distance to Center								
Post entry · entry market	0.058***	0.057**	0.23***	0.25**	-0.042	-0.0020	-0.099*	-0.046
	(0.019)	(0.026)	(0.073)	(0.11)	(0.027)	(0.032)	(0.051)	(0.051)
	[0.00]	[0.04]	[0.00]	[0.01]	[0.15]	[0.98]	[0.14]	[0.36]
Control for Post · Distance	Yes	-	Yes	-	Yes	-	Yes	-
Comparable distance sample	-	Yes	-	Yes	-	Yes	-	Yes
Observations	787	588	262	185	787	588	262	185
Panel B: Traffic Growth								
Post entry · entry market	0.037*	0.050	0.22***	0.25**	-0.052	-0.063	-0.11**	-0.061
	(0.019)	(0.029)	(0.077)	(0.11)	(0.031)	(0.036)	(0.051)	(0.051)
	[0.04]	[0.10]	[0.01]	[0.01]	[0.14]	[0.12]	[0.06]	[0.28]
Control for Post · Growth	Yes	-	Yes	-	Yes	-	Yes	-
Comparable growth rate sample	-	Yes	-	Yes	-	Yes	-	Yes
Observations	787	550	262	187	787	550	262	187

Note: Panel A shows that results are not driven by differences between treatment and control markets in the distance to the center of Hyderabad. Panel B shows that results are not driven by differences between treatment and control markets in customer traffic growth. Market-clustered standard errors appear in parentheses and wild-cluster bootstrap p-values appear in brackets. All regressions include market fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 3: Estimates for 18 Candidate Entry Markets

	Complies with Indian Pharmacopeia				ln(Price per Tablet)			
	All		Non-National		All		Non-National	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post entry	-0.045*	-0.065***	-0.17**	-0.15*	-0.0010	0.0075	0.061	0.18**
	(0.022)	(0.017)	(0.073)	(0.079)	(0.026)	(0.034)	(0.059)	(0.066)
Post entry · entry market	0.046*	0.051**	0.23**	0.14	-0.018	-0.038	-0.12*	-0.29***
	(0.022)	(0.024)	(0.082)	(0.082)	(0.032)	(0.046)	(0.063)	(0.075)
Market demo and health controls	-	Yes	-	Yes	-	Yes	-	Yes
Wild bootstrap p-value (post · entry)	0.06	0.22	0.01	0.32	0.59	0.56	0.07	0.05
Proportional selection δ	-	-1.53	-	1.06	-	-2.27	-	-3.59
Observations	707	707	228	228	707	707	228	228
R^2	0.07	0.08	0.26	0.37	0.11	0.11	0.18	0.25

Note: The table reproduces the main estimates from the paper for the 18 candidate entry markets and excluding 2 markets where the chain did not consider entry. Market-clustered standard errors appear in parentheses. All regressions include market fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 4: Robustness to Unobservable Trends

Dependent variable:	Complies with IP				ln(Price per Tablet)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post entry	-1.98	-0.0054	-0.81**	0.58***	-1.87	0.23	-0.75**	0.53***
	(1.42)	(0.29)	(0.33)	(0.19)	(1.14)	(0.17)	(0.34)	(0.16)
Post entry · entry market	0.23**	0.15***	0.14***	0.19**	-0.19**	-0.11**	-0.081	-0.072
	(0.082)	(0.046)	(0.041)	(0.068)	(0.082)	(0.052)	(0.071)	(0.043)
Post entry · baseline:								
-Market demographic controls	Yes	-	-	-	Yes	-	-	-
-Market health controls	-	Yes	-	-	-	Yes	-	-
-Pharmacy characteristics	-	-	Yes	-	-	-	Yes	-
-Dependent variable (pharm. mean)	-	-	-	Yes	-	-	-	Yes
Wild bootstrap p-value (post · entry)	0.06	0.02	0.01	0.01	0.04	0.07	0.31	0.12
Proportional selection δ	-0.37	0.50	1.60	1.31	-5.45	-0.71	1.26	6.20
Observations	262	262	262	262	262	262	262	262
R^2	0.27	0.28	0.34	0.27	0.22	0.21	0.28	0.42

Note: Regressions in this table control for the interaction of 'post entry' and baseline market characteristics in order to show that differential trends by these characteristics do not confound the estimates for the impact of chain entry. Market-clustered standard errors appear in parentheses. All regressions include market fixed effects. All regressions are limited to the sample of non-national brands. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 5: A Test for Treatment Spillovers into Control Markets

Dependent variable	Complies with IP				ln(Price per Tablet)			
Manufacturers	All		Non-National		All		Non-National	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post	-0.044	-0.071*	-0.19**	-0.24	0.032	0.045	0.11	0.17*
	(0.026)	(0.036)	(0.085)	(0.14)	(0.031)	(0.037)	(0.067)	(0.092)
Post · entry market	0.045	0.071*	0.24**	0.30*	-0.051	-0.064	-0.16**	-0.23**
	(0.026)	(0.036)	(0.092)	(0.15)	(0.036)	(0.042)	(0.070)	(0.095)
Drop control markets within	5 km	10 km	5 km	10 km	5 km	10 km	5 km	10 km
Wild bootstrap p-value (post · entry)	0.14	0.07	0.00	0.01	0.16	0.21	0.04	0.05
Observations	629	471	204	153	629	471	204	153
R^2	0.06	0.05	0.26	0.27	0.13	0.14	0.24	0.21

Note: The table reproduces quality and price results while excluding the control markets that are nearby treatment markets. Market-clustered standard errors appear in parentheses. Odd columns omit 4 control markets that are within 5 kilometers by road of the nearest treatment market. Even columns omit 8 control markets that are within 10 kilometers by road of the nearest treatment market. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 6: The Impact of Chain Entry on Consumer Preferences

	Perceived Importance of:					
	Drug Quality		Store Convenience		Store Familiarity	
	(1)	(2)	(3)	(4)	(5)	(6)
Round 2 · entry market	0.28***	0.28***	0.045	0.076	-0.014	0.006
	(0.077)	(0.079)	(0.063)	(0.053)	(0.069)	(0.092)
Round 3 · entry market	0.28***	0.30***	-0.003	0.019	-0.13**	-0.11
	(0.074)	(0.073)	(0.014)	(0.050)	(0.047)	(0.071)
Market demo and health controls	-	Yes	-	Yes	-	Yes
Wild bootstrap p-value:						
Round 2 · entry	0.00	0.00	0.51	0.25	0.84	0.95
Round 3 · entry	0.00	0.00	0.87	0.74	0.01	0.20
Proportional selection δ:						
Round 2 · entry	-	-1.39	-	-3.10	-	-0.05
Round 3 · entry	-	-2.08	-	-0.46	-	0.43
Observations	2575	2575	2632	2632	2631	2631
R^2	0.08	0.10	0.09	0.12	0.23	0.24

Note: The table shows impact of chain entry on the perceived importance of drug quality, store convenience, and store familiarity among consumers. Market-clustered standard errors appear in parentheses. All regressions include market fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 7: Chain Entry and Incumbent Shopper Characteristics

Dependent variable:	ln(Income)	Education	Household size	Scheduled caste/tribe	Owns a vehicle
	(1)	(2)	(3)	(4)	(5)
Round 2 · entry market	-0.045	-0.41	0.18	-0.010	0.033
	(0.17)	(1.00)	(0.23)	(0.079)	(0.13)
Round 3 · entry market	0.0085	-0.033	-0.27	-0.027	0.084
	(0.14)	(0.86)	(0.17)	(0.056)	(0.097)
Wild bootstrap p-value					
Round 2 · entry	0.83	0.73	0.45	0.90	0.81
Round 3 · entry	0.95	0.97	0.16	0.64	0.41
Observations	2224	2224	2224	2224	2224
R^2	0.06	0.06	0.07	0.03	0.04

Note: The table shows the impact of chain entry on the characteristics of incumbent pharmacy shoppers. Market-clustered standard errors appear in parentheses. The sample is limited to shoppers at incumbent pharmacies. All regressions include market fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.