Left-Digit Bias, Investor Attention and Trading Behavior

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Abstract

Abstract here

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We show left-digit bias in stock-selling behavior of individual investors. Left-digit bias is the tendency to focus on the leftmost digit of a number while partially ignoring other digits (Poltrock and Schwartz, 1984). Our contribution is to show that investors are disproportionately attentive to the leftmost digit in their trading choices, the salience of prices matters for investment choices (is this what we think is going on? This is similar to the rank effect finding of Hartzmark (2015), whereby either top-ranked or bottom-ranked stocks by return since purchase are those most likely to be sold. We contribute to the broader literature on left-digit bias, including Lacetera et al. (2012) and Shlain (2018). Our study contributes to our understanding of when and why investors sell stocks.

1 Data and Sample Selection

We use the Barclays data. We first do some basic data cleaning, with details shown in Table A1. EQ:[Note that in this report I have added one additional step, I excluded all trades outside market hours 8am to 4:30pm, which are likely reflecting the execution of limit orders.]

We then choose a sample for analysis. A key element in our analysis is to draw a price increasing sample and a price decreasing sample, because we will show that the probability of sale increases with a change in the left digit both from below and from above.

We define these samples as follows. First, using the example of price increasing, we identify the first day in each calendar quarter on which an investor made a login to their account. We then define the price increasing sample as the set of login days within the quarter for which the prices on subsequent login days were always above the price on the first day and the left-digit had changed within the quarter on at least one subsequent login-day. We define the price decreasing sample as the set of login days within the quarter for which the prices on subsequent login days were always below the price on the first day and the left-digit had changed within the quarter on at least one subsequent login-day. Our samples are based on quarters and individual $\times$ login days during the quarter. Due to the immense size of the data, we further restrict to a 30% random sample.

The idea behind this sample restriction is that we need to focus on changes in left-digit that the investor actually saw. By restricting to changes in the left digit as seen by investors on login-days, we know that the investor saw the below-price and then subsequently the above-price (or vice versa).

We show later that results are unchanged when we modify the period that defines a sample to either a month or a year.

Summary statistics are shown in Table A2. Note, there are four units of left-digit in the data, pennies, tens of pennies, pounds and tens of pounds (there are only a few cases of hundreds of pounds). So, the left-digit changes of interest are pence to tens of pence, tens of pence to pounds, and pounds to tens of pounds (plus a few cases of tens of pounds to hundreds of pounds). Most stocks in the samples are prices in the range £1.10 to £10.10. A histogram of

prices for all investor × login days is shown in Figure A1.

EQ:[We are concerned about the effect of limit orders in the data. I have redone the analysis using the main samples described above that exclude sells outside the market hours but with some modifications in the analysis:

- Market-Price: Prices and left digits are defined using the **market price at the end of the day for all the stocks**.
- Sell-Price: **For sells, prices and left digits are defined using the exact price at which the stock was sold**. For the remaining days (when the stocks were not sold), prices and left digits are defined based in the market price at the end of the day.
- Sell-Price-No-Login-Yesterday: Uses the same definition of prices and left digits used in Sell-Price but **it excludes sells with a login the day before. It also excludes sells on Monday with any login on Saturday or Sunday**.
- Sell-Price-FTSE100: Uses the same definition of prices and left digits used in Sell-Price but **it includes only FTSE100 stocks**.

The number of sells is reduced considerably in the last two analysis (Sell-Price-No-Login-Yesterday and Sell-Price-FTSE100) and some patterns are not clear in the plots. For instance, the Price Increasing sample has 27111 sells in the Sell-Price analysis; but only 10574 sells, in the Sell-Price-No-Login-Yesterday analysis (because most investors tend to log in the day before and now we are excluding these sells); and only 6464 sells, in the Sell-Price-FTSE100 analysis.]

2 Results

Our main results from the Market-Price analysis are shown in Figure 1, from the Sell-Price analysis, in Figure 2, from the Sell-Price-No-Login-Yesterday analysis, in Figure 3, and from the Sell-Price-FTSE100 analysis, in Figure 4. Figure 1 stack all investor × stock × login days by the leftmost two digits. The figure plots in the left-side the probability of sale by leftmost digits, and in the right-side it plots the probability of sale by the leftmost two digits. For example, the left-side plot stacks up stocks which pass from 9 pence to 10 pence, 29 pence to 30 pence, 199 pence to 200 pence, and so on in every case in which the leftmost digit changes. These examples each enter the plot at X9 to Y0, where X and Y are integer units and $Y = X + 1$. The left-side plots show clear jumps in the probability of sale when the stock price crosses the leftmost digit; the right-side plots also show this phenomena, with the red bar denoting base 10 leftmost two digit prices. In Panel A there is a jump in probability of sale when the price crosses the left digit from below, e.g. 19 pence to 20 pence; in Panel B there is a jump when the price crosses the left digit from above, e.g. 20 pence to 19 pence. Note that in general the probability of sale is higher in the price increasing sample than in the price decreasing sample, consistent with the disposition effect.

Note that the jump at Y0 is more pronounced in Figure 1 than in Figure 2. This could

reflect that on days in which people observed a changed in the prices' left digits they were willing to sell, but they do not necessarily sold the stocks at Y0, perhaps because some stocks were less liquid or perhaps because they were not really targeting a Y0-price but an slightly higher price due to some optimism.

The results for the Sell-Price-No-Login-Yesterday analysis in Figure 3 show the same pattern, a jump at Y0 and a slow decay, even though this analysis excludes more than half of the sell observations. However, the analysis for FTSE100 stocks in Figure 4 shows smaller jumps. By using only this subset of stocks, we loss about four fifths of the sell observations and the patterns might not represent a typical investor.

Nevertheless, if limit orders were a problem, we should see an spike in the Sell-Price-FTSE100 analysis; however, we observe a small jump with a slow decay, which suggest that our effects are not driven by limit orders. And limit orders could not explain the peak at X9 in Figure 4 Panel B.

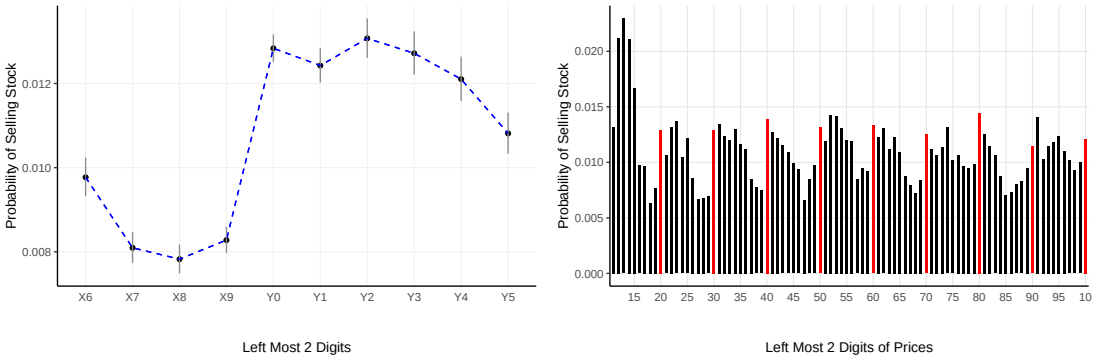
In Figure 5 to Figure 8 (for Price Increasing Samples), and in Figure 9 to Figure 12 (for Price Decreasing Samples), we split the analysis by different price ranges. **Patterns are not clear for stocks cheaper than £1 or more expensive than £11 because of the small number of observations in these price range**.

In Figure A6 to Figure A13, we use the annual and monthly samples instead of the quarterly samples. We observe jumps at Y0 but of small magnitude.

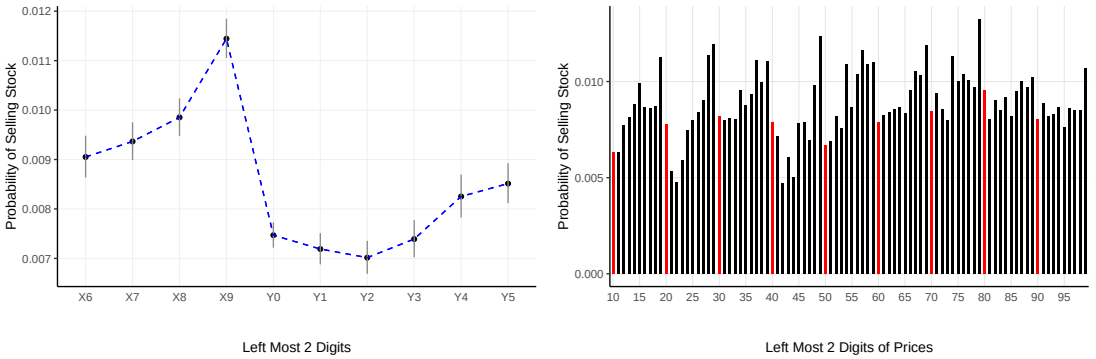
Figure A2 to Figure A5 replicate the results using sell days only.

Figure 1: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Market-Price, Login-Days

(A) Price Increasing

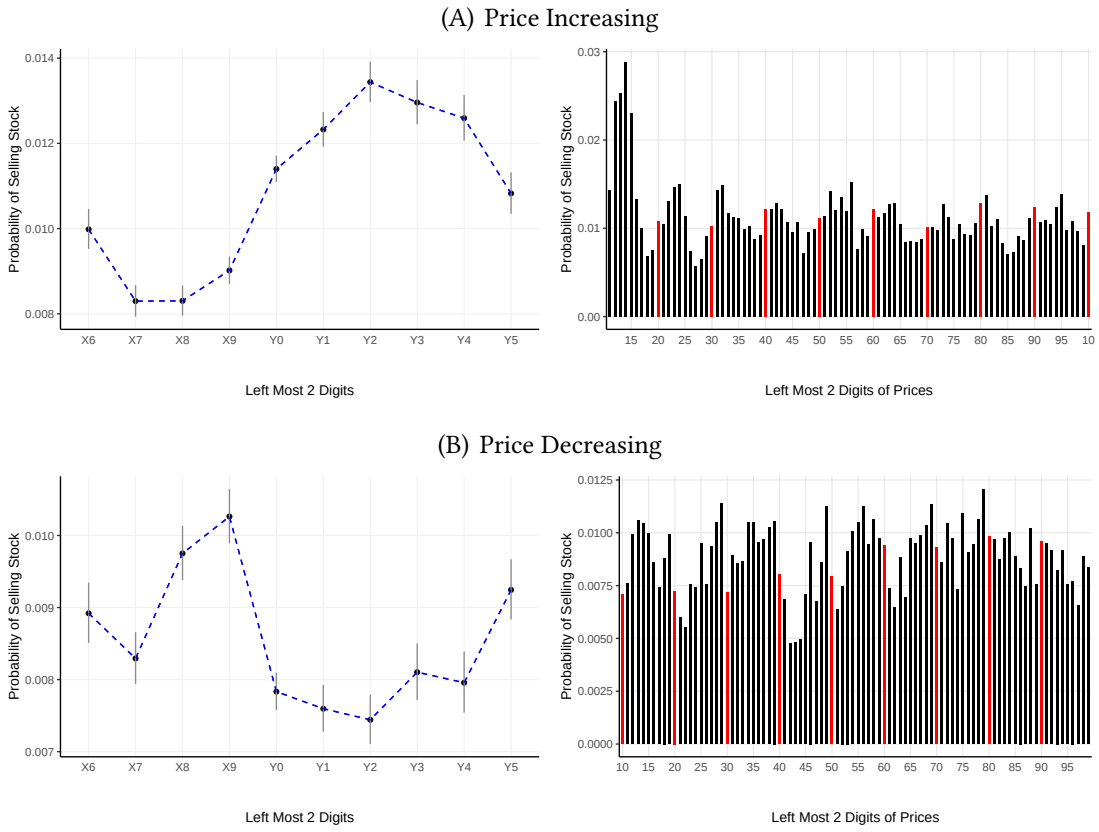


(B) Price Decreasing



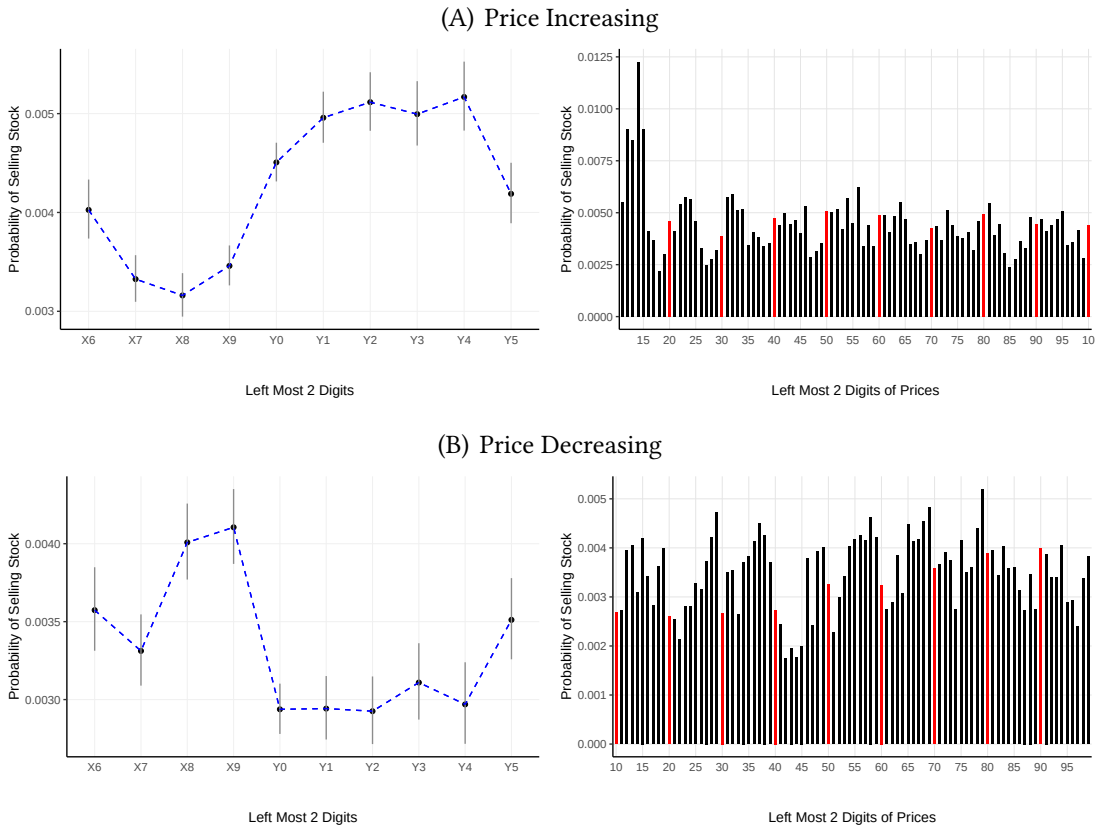
Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure 2: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price, Login Days



Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

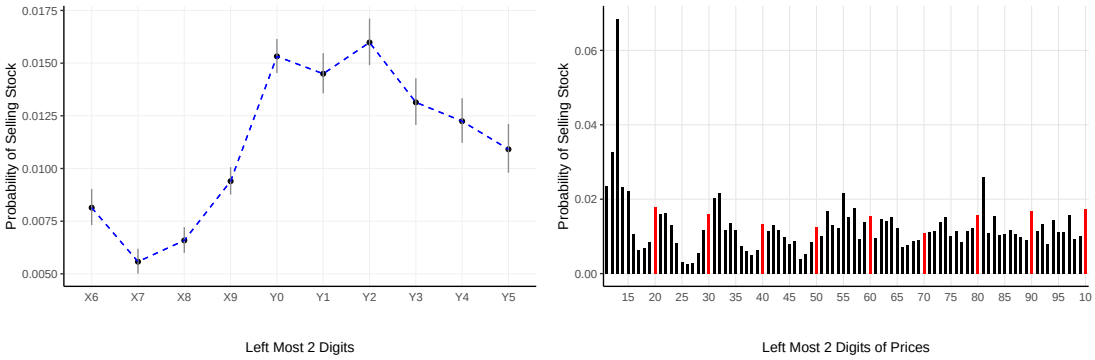
Figure 3: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price-No-Login-Yesterday, Login-Days



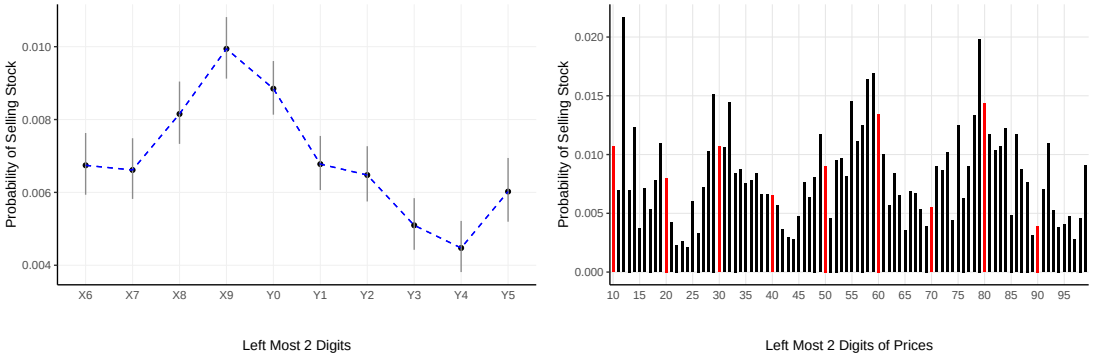
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure 4: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price-FTSE100, Login-Days

(A) Price Increasing



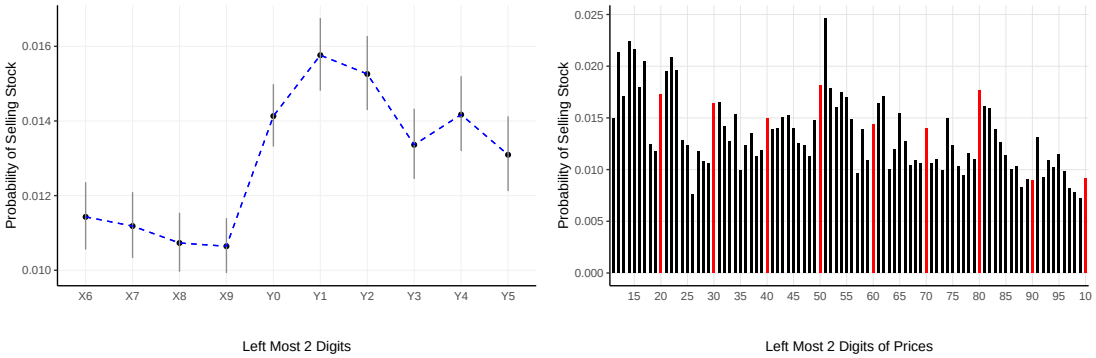
(B) Price Decreasing



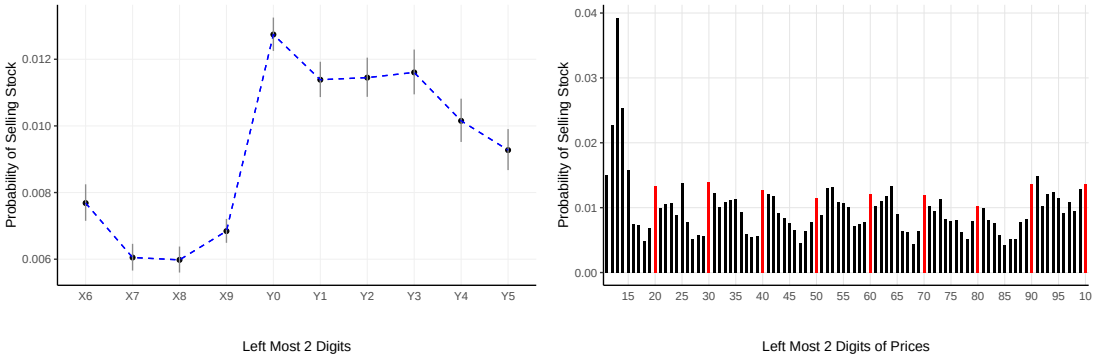
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure 5: Leftmost Stock Price Digit and Probability of Sale
Prices Increasing Sample by Price Range
Market-Price, Login-Days

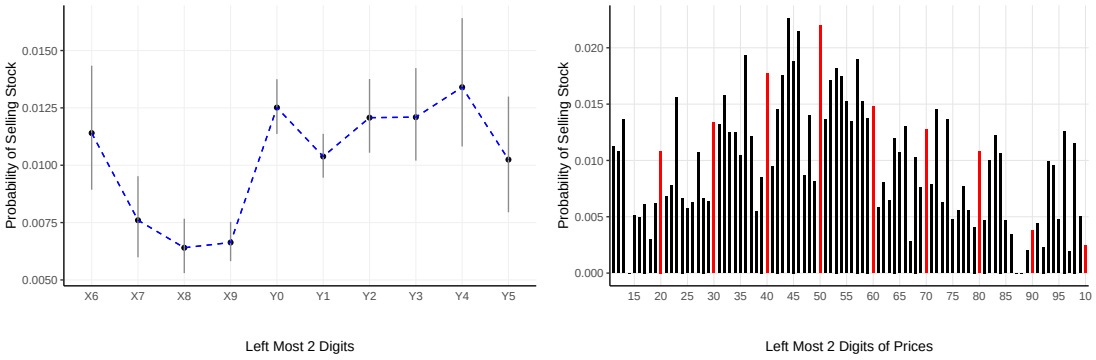
(A) Price = £0.11 to £1.01



(B) Price = £1.01 to £10.1



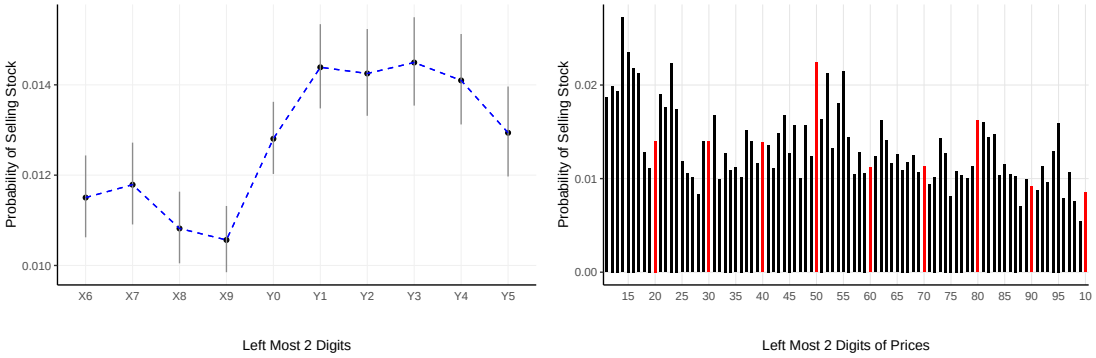
(C) Price = £11 to £101



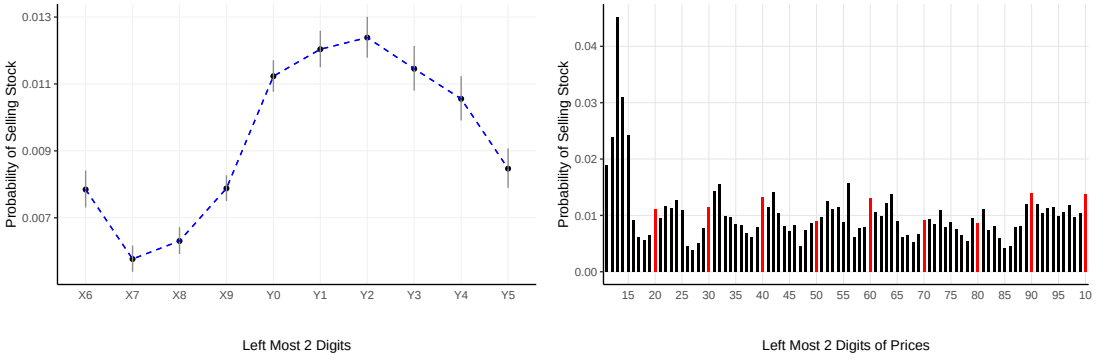
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 25% of the observations in the prices increasing sample; Panel B, to 55%; and Panel C, to 8%.

Figure 6: Leftmost Stock Price Digit and Probability of Sale
Prices Increasing Sample by Price Range
Sell-Price, Login-Days

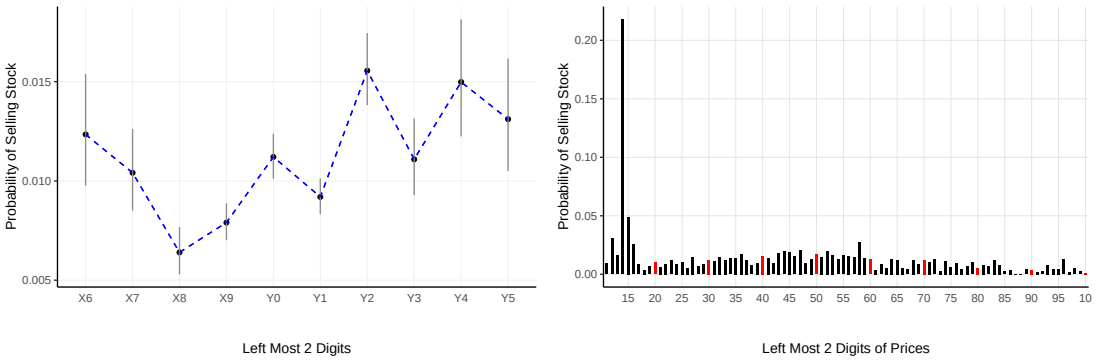
(A) Price = £0.11 to £1.01



(B) Price = £1.01 to £10.1



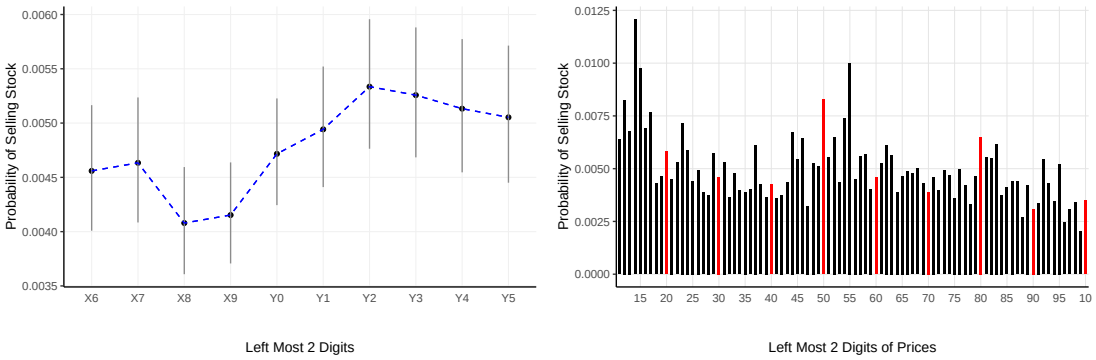
(C) Price = £11 to £101



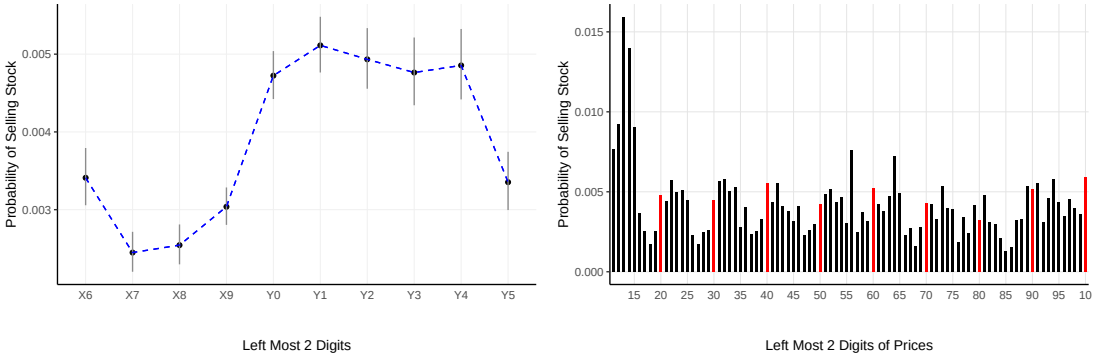
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 25% of the observations in the prices increasing sample; Panel B, to 55%; and Panel C, to 8%.

Figure 7: Leftmost Stock Price Digit and Probability of Sale
Prices Increasing Sample by Price Range
Sell-Price-No-Login-Yesterday, Login-Days

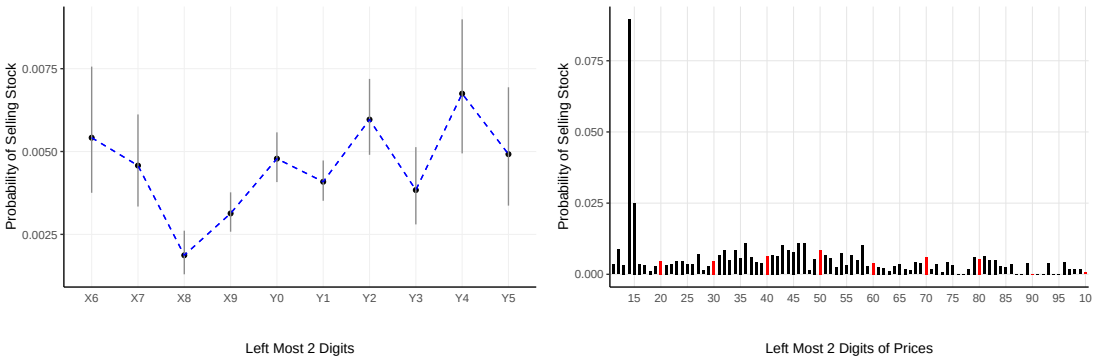
(A) Price = £0.11 to £1.01



(B) Price = £1.01 to £10.1



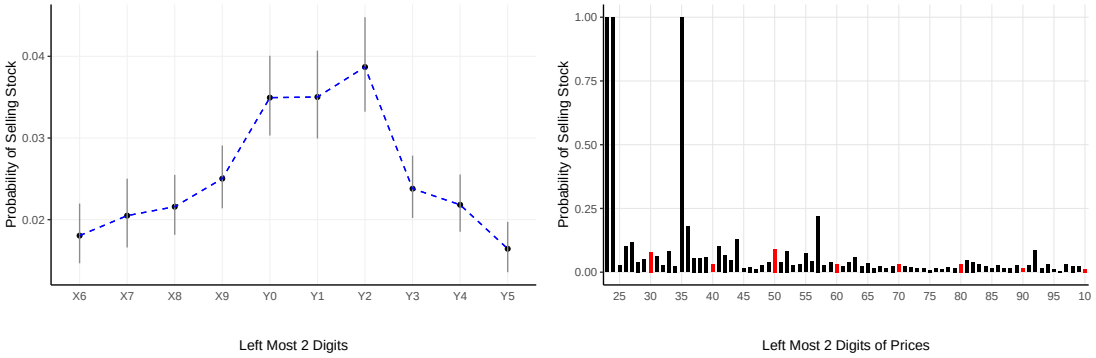
(C) Price = £11 to £101



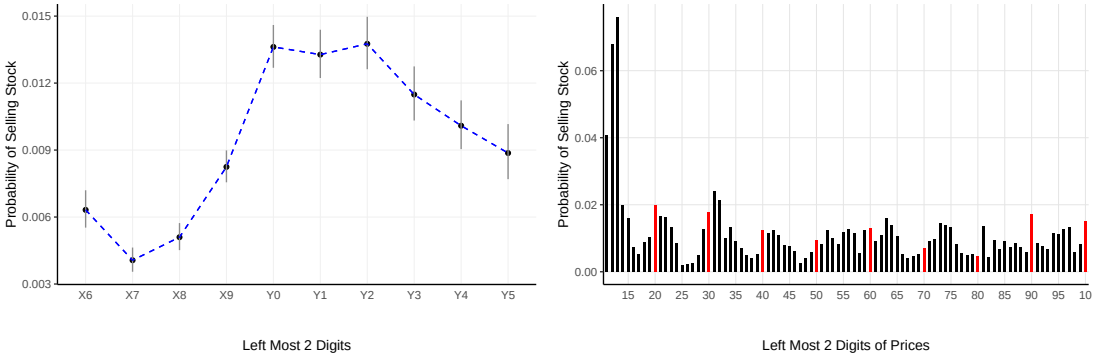
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 25% of the observations in the prices increasing sample; Panel B, to 55%; and Panel C, to 8%.

Figure 8: Leftmost Stock Price Digit and Probability of Sale
Prices Increasing Sample by Price Range
Sell-Price-FTSE100, Login-Days

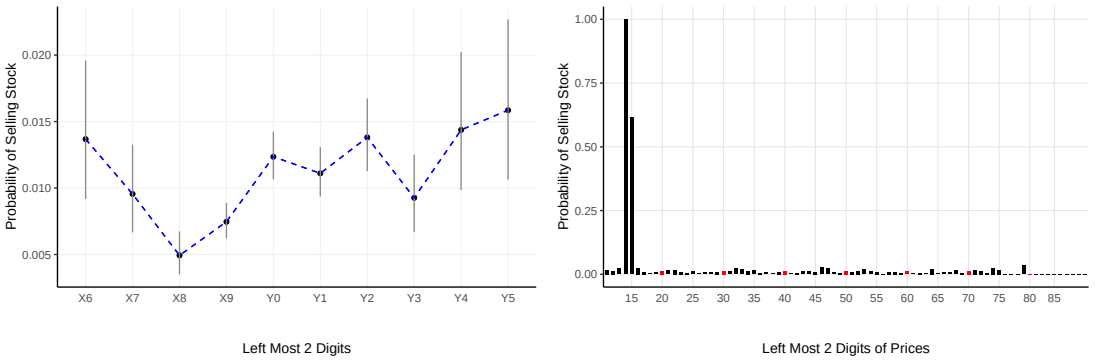
(A) Price = £0.11 to £1.01



(B) Price = £1.01 to £10.1



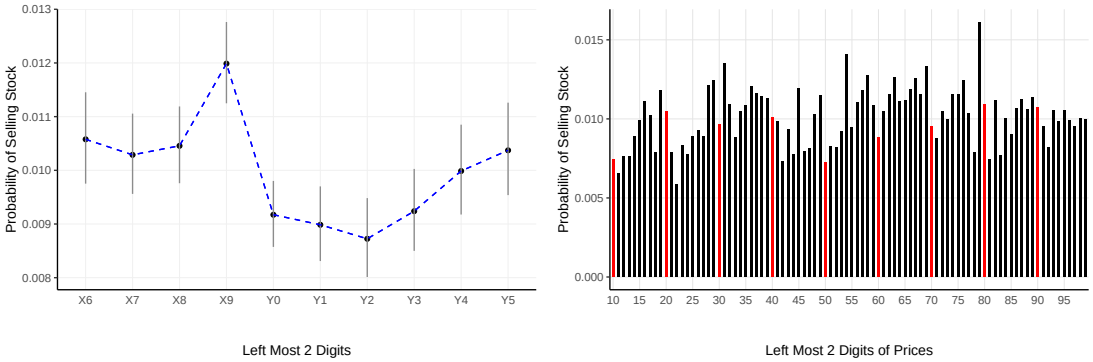
(C) Price = £11 to £101



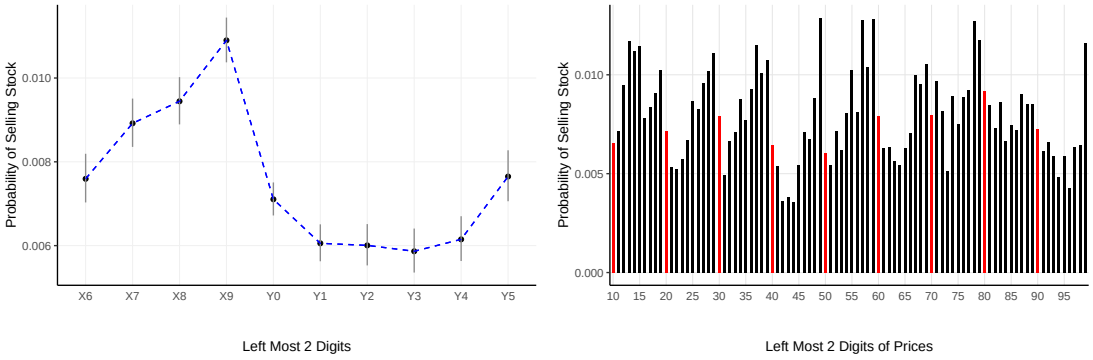
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 25% of the observations in the prices increasing sample; Panel B, to 55%; and Panel C, to 8%.

Figure 9: Leftmost Stock Price Digit and Probability of Sale
Prices Decreasing Sample by Price Range
Market-Price, Login-Days

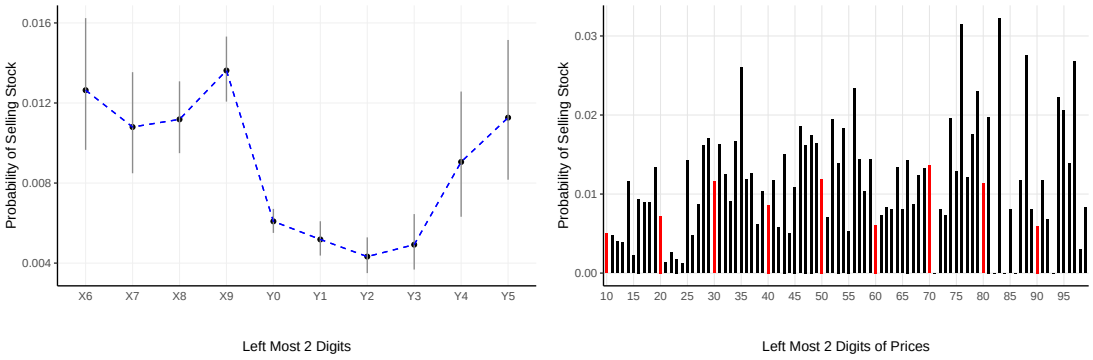
(A) Price = £0.10 to £1.00



(B) Price = £1.00 to £10.0



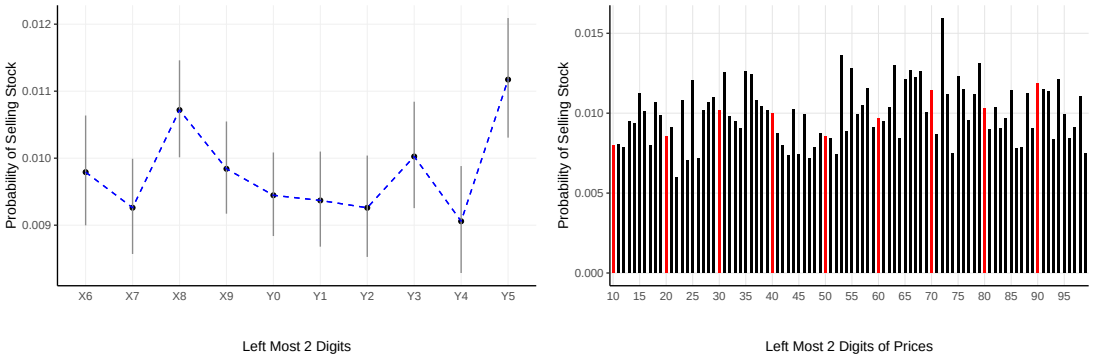
(C) Price = £10 to £100



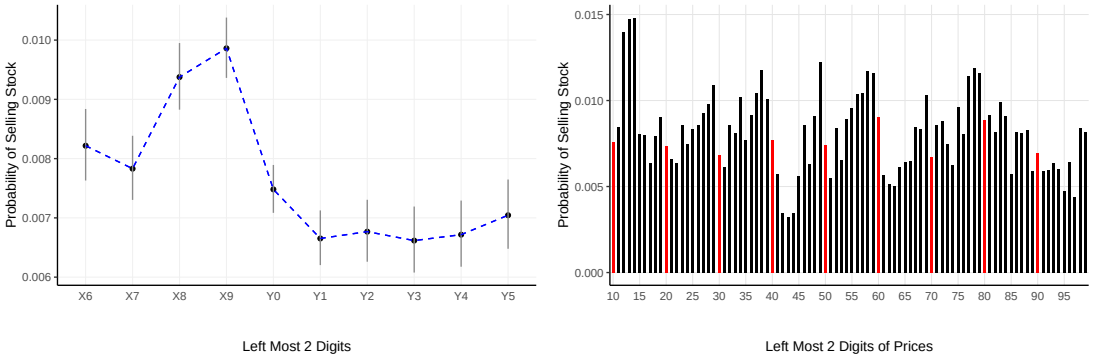
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 27% of the observations in the prices decreasing sample; Panel B, to 43%; and Panel C, to 7%.

Figure 10: Leftmost Stock Price Digit and Probability of Sale
Prices Decreasing Sample by Price Range
Sell-Price, Login-Days

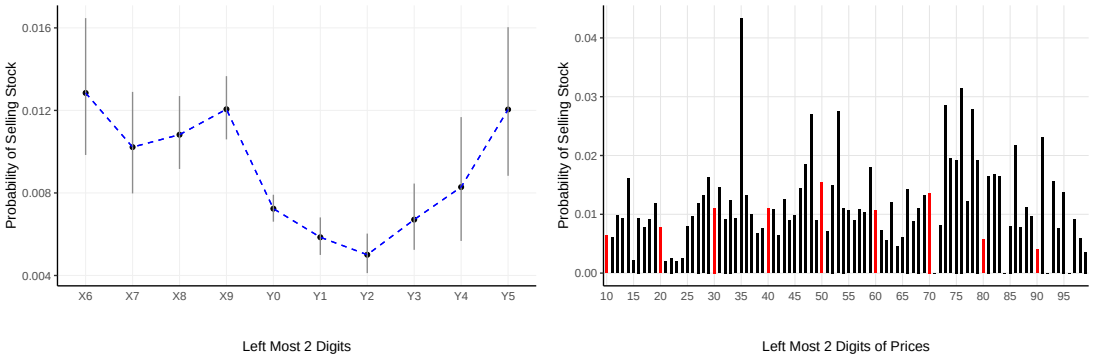
(A) Price = £0.10 to £1.00



(B) Price = £1.00 to £10.0



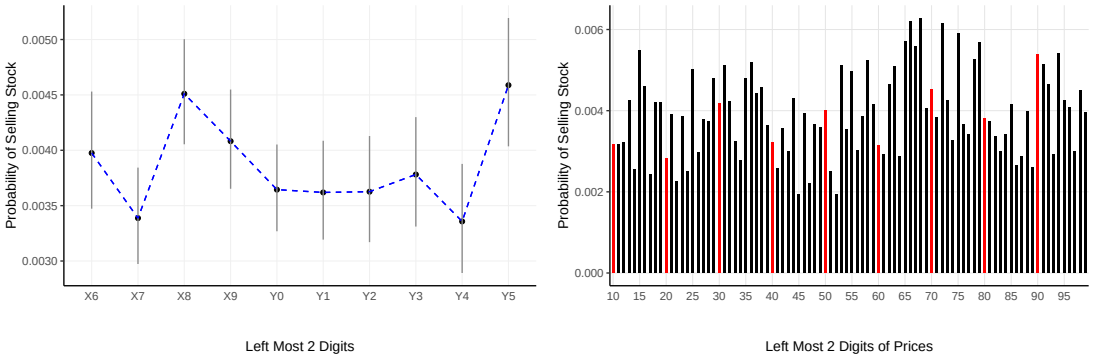
(C) Price = £10 to £100



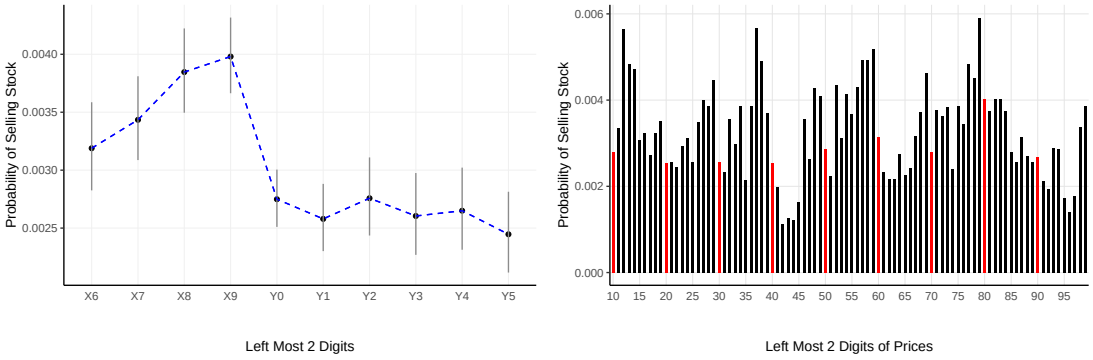
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 27% of the observations in the prices decreasing sample; Panel B, to 43%; and Panel C, to 7%.

Figure 11: Leftmost Stock Price Digit and Probability of Sale
Prices Decreasing Sample by Price Range
Sell-Price-No-Yesterday-Login, Login-Days

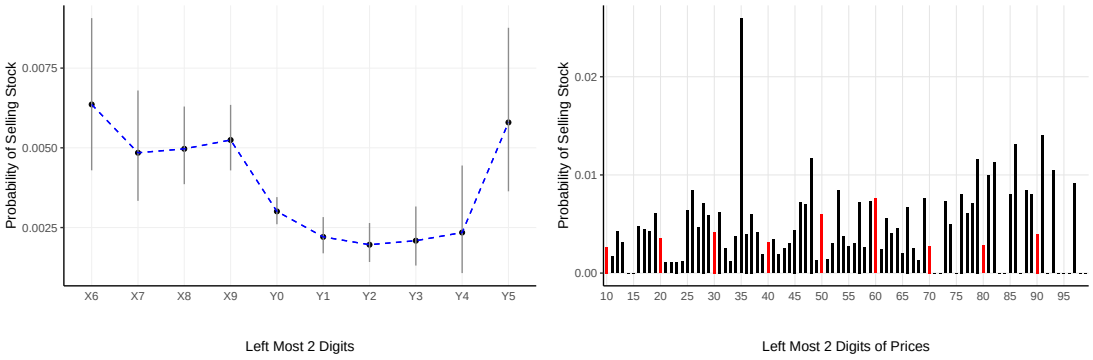
(A) Price = £0.10 to £1.00



(B) Price = £1.00 to £10.0



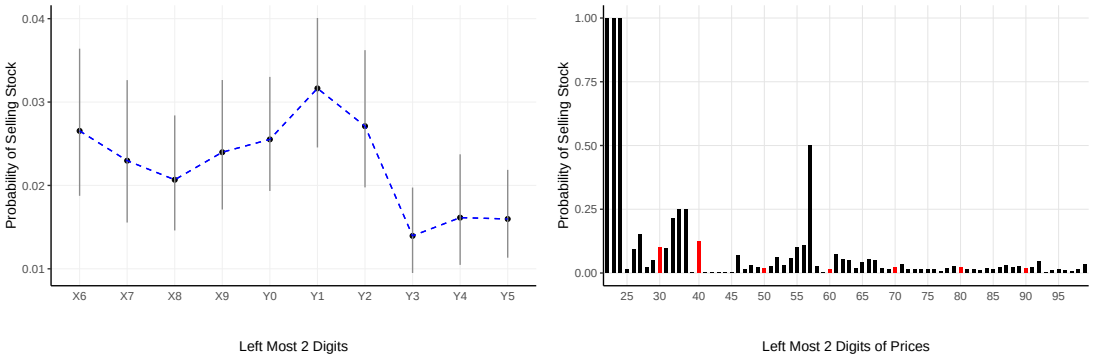
(C) Price = £10 to £100



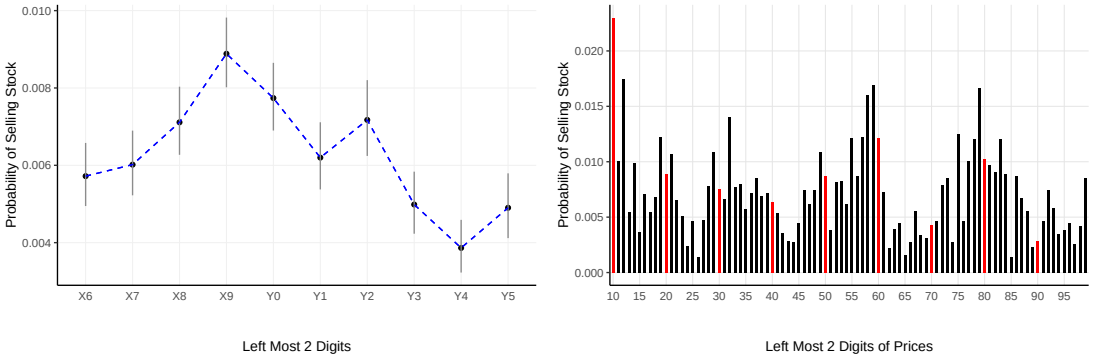
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 27% of the observations in the prices decreasing sample; Panel B, to 43%; and Panel C, to 7%.

Figure 12: Leftmost Stock Price Digit and Probability of Sale
Prices Decreasing Sample by Price Range
Sell-Price-FTSE100, Login-Days

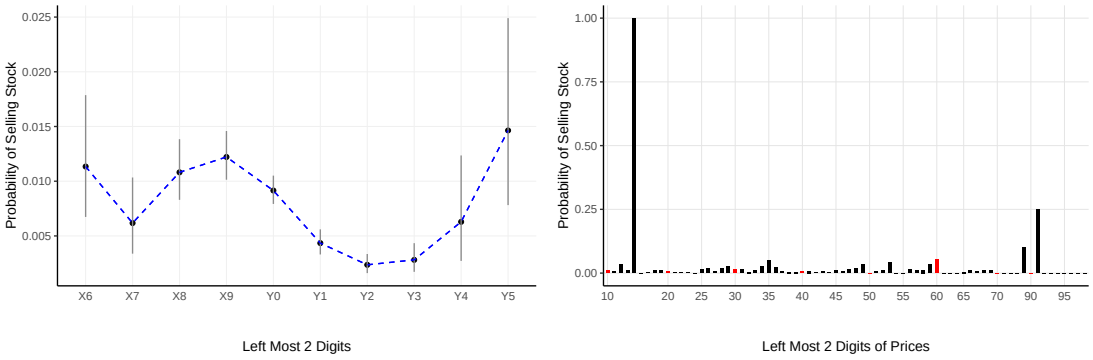
(A) Price = £0.10 to £1.00



(B) Price = £1.00 to £10.0



(C) Price = £10 to £100



Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.). Panels A, B and C show equal size bins of 1p, 10p and £1, respectively. Panel A corresponds to 27% of the observations in the prices decreasing sample; Panel B, to 43%; and Panel C, to 7%.

Table A1: Sample Selection

	Accounts	Logins	Transactions	Sells
Unrestricted Sample	45919	67734059	1228755	493041
Drop due to:				
Inactive Accounts	14370	7932474	46982	19562
Unmatched Prices	306	13009351	129314	49012
At Least Two Stocks in Portfolio	3062	720291	76539	32652
Missing Demographic Data	1137	1793831	37427	16400
Starting Position Days	23	367341	331557	25479
Trades Outside Market Hours	0	7659	7659	7659
Baseline sample	27021	43903112	599277	342277

Note: The unrestricted sample contains 155,300 accounts. We use a 30% random sample of accounts. The table detail the steps in sample selection. Logins, Transactions, and Sells reflect the number of observations for each category at the Account × Stock × Day level.

Table A2: Summary Stats, Quarterly Sample
Sell-Price

Panel (A): Baseline Sample

	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Price on Login Days £	43,903,112	7.942	26.178	0.000	1.153	3.050	7.642	15,051.630
Price on Sell Days £	3,341,054	7.103	24.523	0.000	0.832	2.646	6.674	3,589.000
Price of Stocks Sold £	342,277	6.848	16.483	0.000	0.861	2.714	6.648	1,771.425

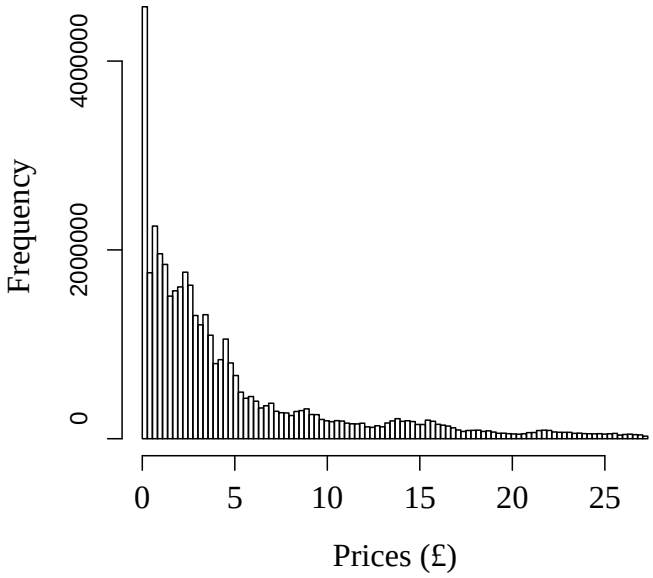
Panel (B): Price Increasing Sample

	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
All Stocks	2,502,458	6.435	23.446	0.000	0.739	2.993	6.175	3,600.000
Stocks with Prices Between £0.11 to £1.01	616,502	0.599	0.257	0.110	0.382	0.628	0.811	1.010
Stocks with Prices Between £1.1 to £10.1	1,370,573	4.890	2.310	1.100	2.955	4.569	6.600	10.100
Stocks with Prices Between £11 to £101	192,445	35.668	22.223	11.000	19.720	29.765	48.000	100.995

Panel (C): Price Decreasing Sample

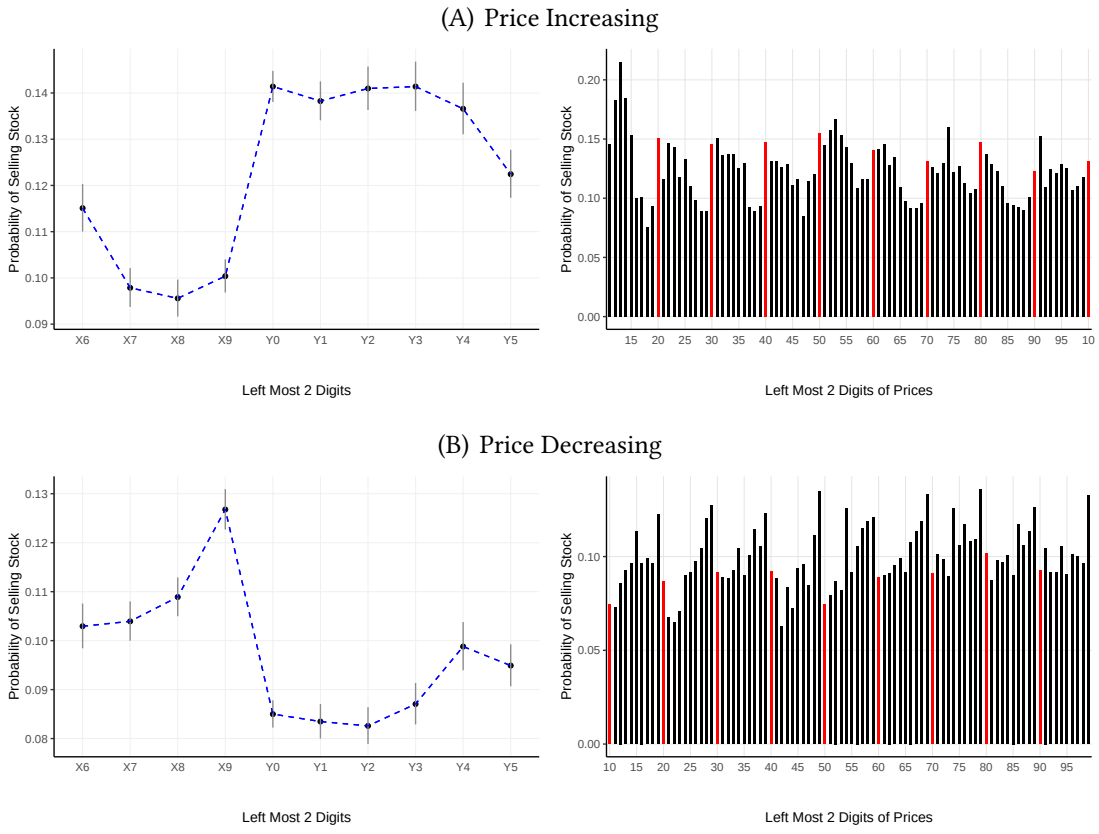
	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
All Stocks	2,527,998	4.259	20.172	0.000	0.165	1.025	4.513	3,284.000
Stocks with Prices Between £0.10 to £1.0	688,621	0.511	0.270	0.100	0.275	0.485	0.750	1.000
Stocks with Prices Between £1 to £10	1,096,091	4.517	2.508	1.000	2.366	4.134	6.231	10.000
Stocks with Prices Between £10 to £100	180,395	25.807	18.962	10.000	10.934	20.880	30.360	99.990

Figure A1: Histogram of Stock Prices



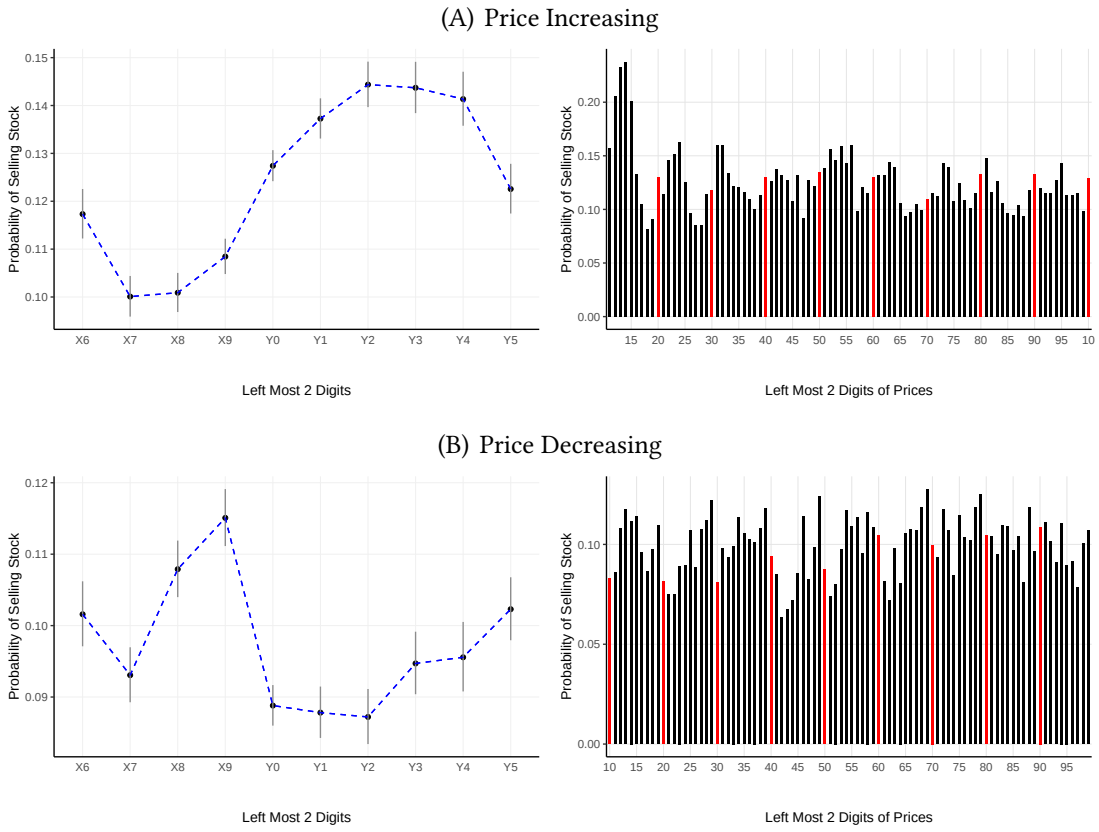
Note: Figure shows the histogram of prices on login days. Outliers above the 95 percentile are excluded.

Figure A2: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Market-Price, Sell-Days



Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

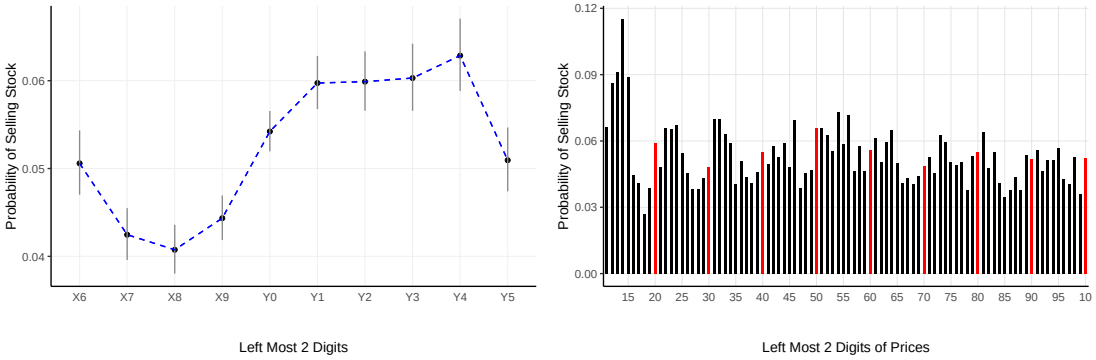
Figure A3: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price, Sell-Days



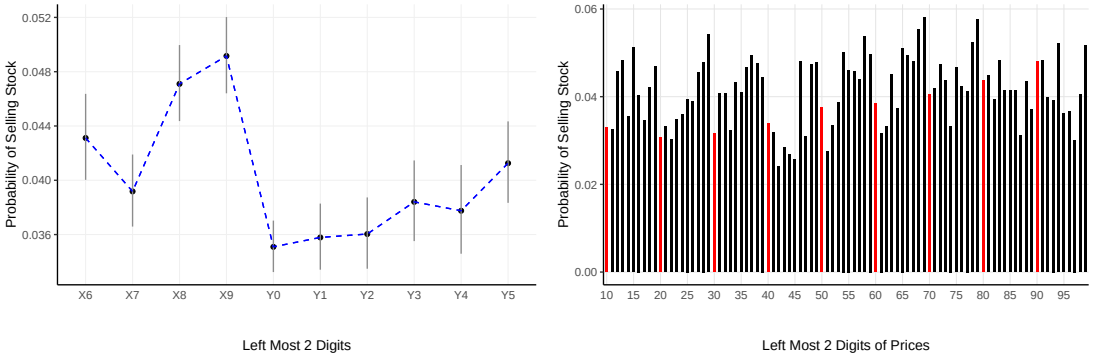
Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A4: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price-No-Login-Yesterday, Sell-Days

(A) Price Increasing



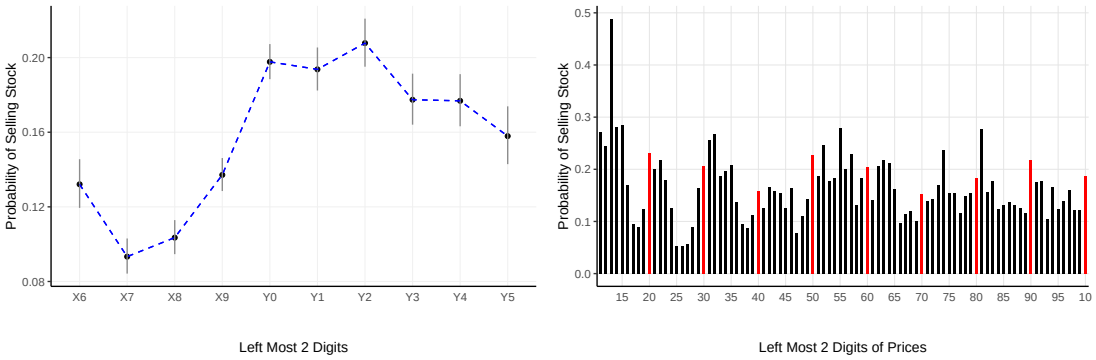
(B) Price Decreasing



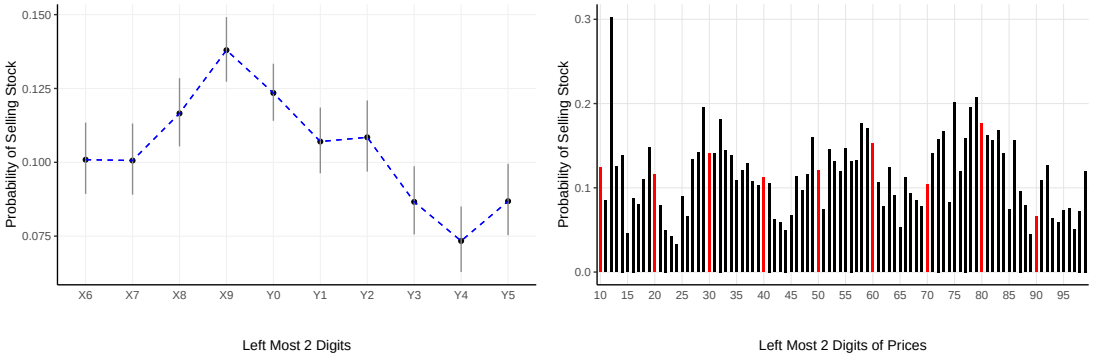
Note: £Y in the X-axes is equivalent to £$X + 1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A5: Leftmost Stock Price Digit and Probability of Sale, Quarterly Sample
Sell-Price-FTSE100, Sell-Days

(A) Price Increasing



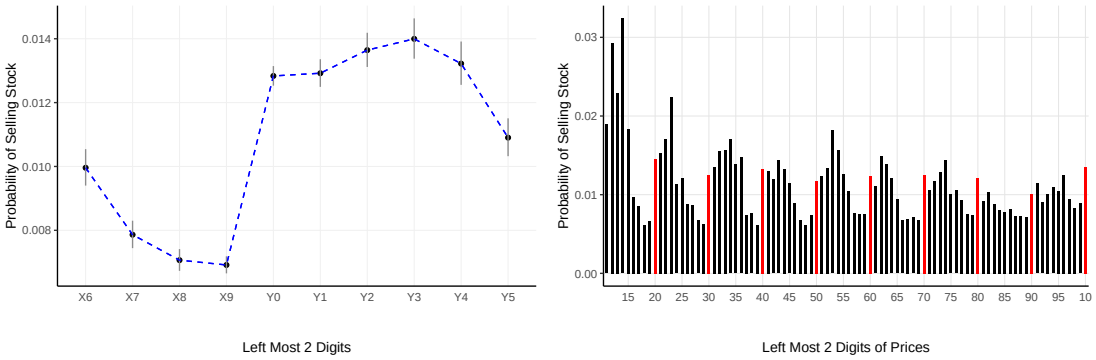
(B) Price Decreasing



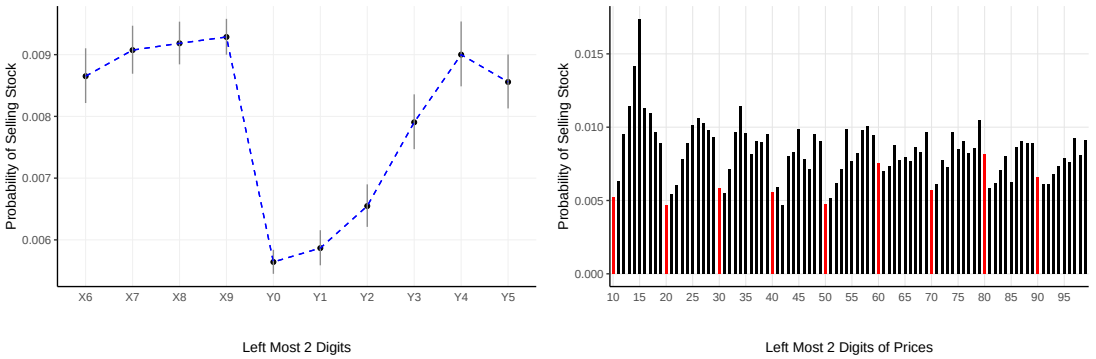
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A6: Leftmost Stock Price Digit and Probability of Sale, Monthly Sample
Market-Price, Login-Days

(A) Price Increasing

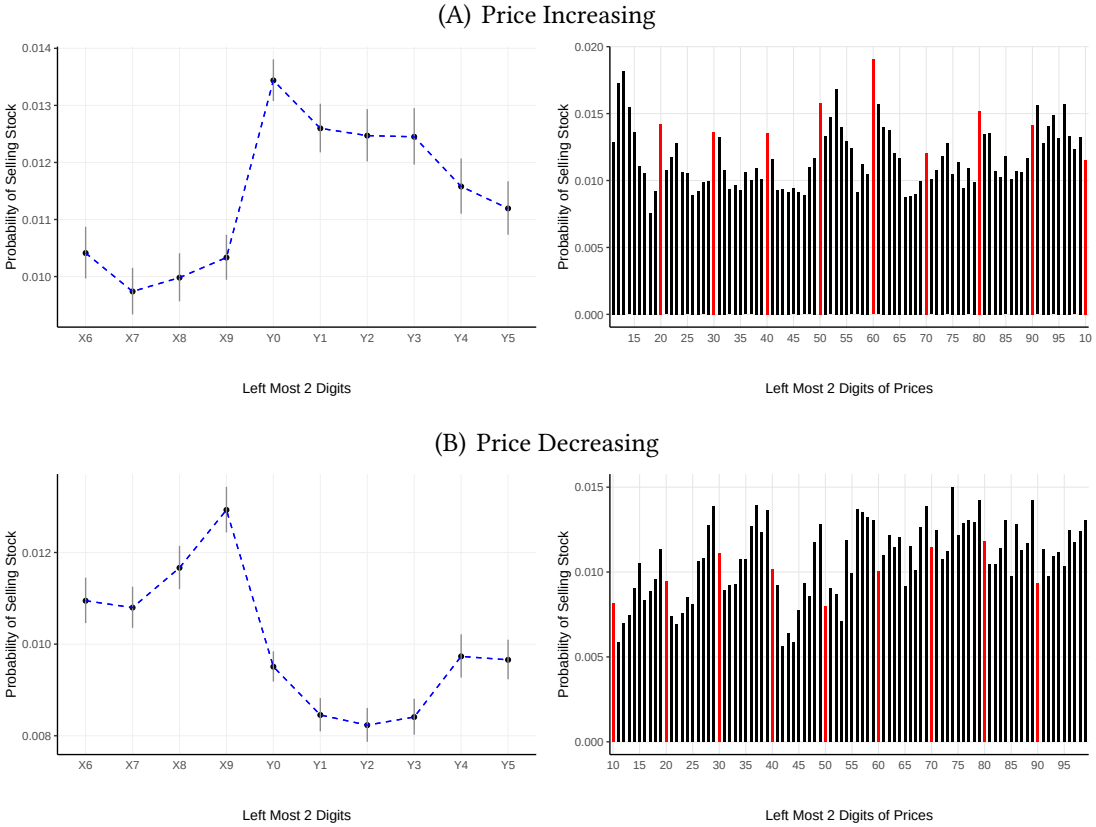


(B) Price Decreasing



Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

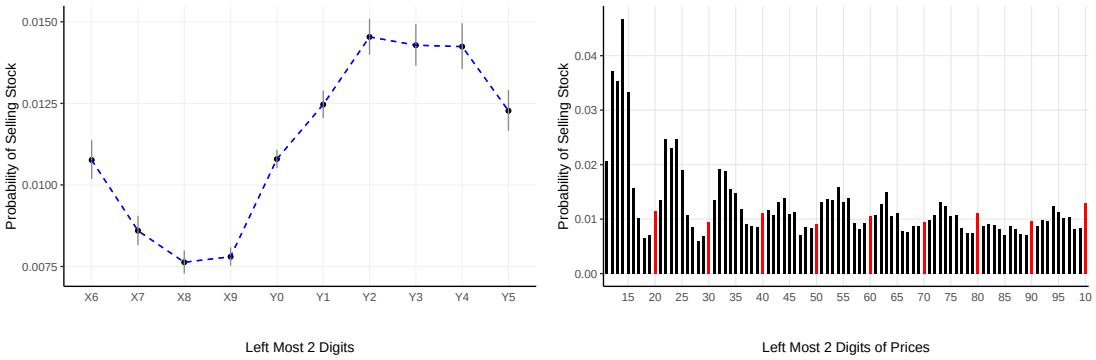
Figure A7: Leftmost Stock Price Digit and Probability of Sale, Annual Sample
Market-Price, Login-Days



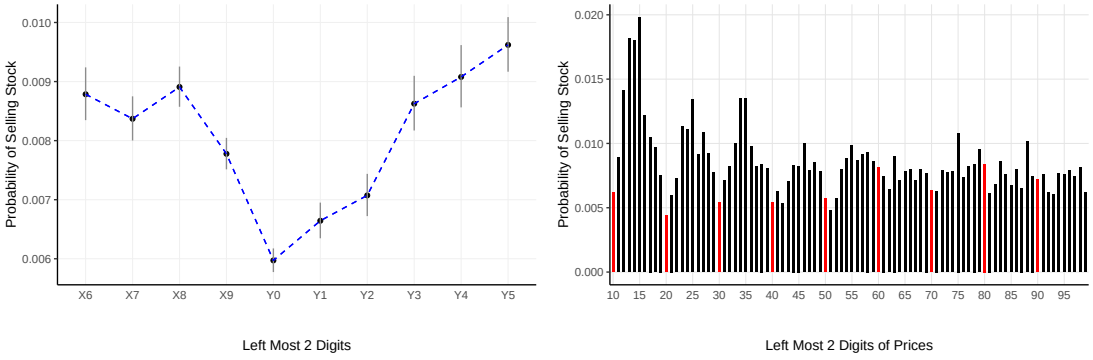
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A8: Leftmost Stock Price Digit and Probability of Sale, Monthly Sample
Sell-Price, Login-Days

(A) Price Increasing

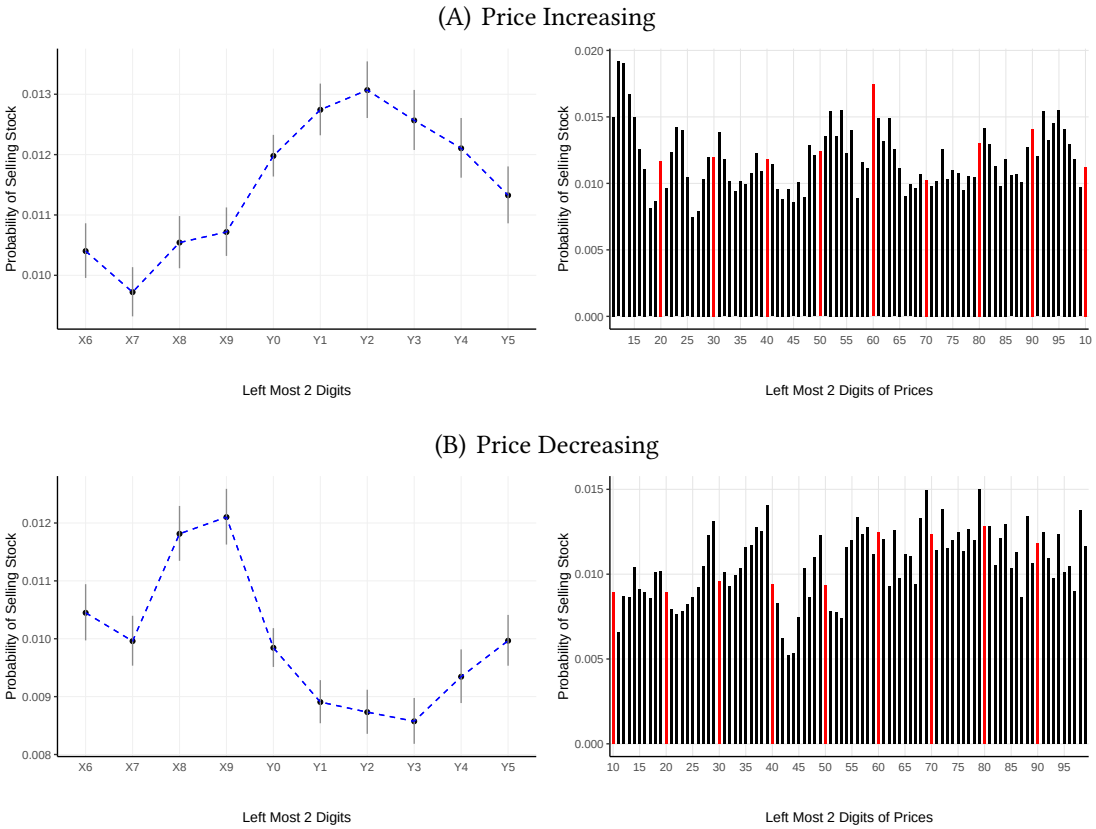


(B) Price Decreasing



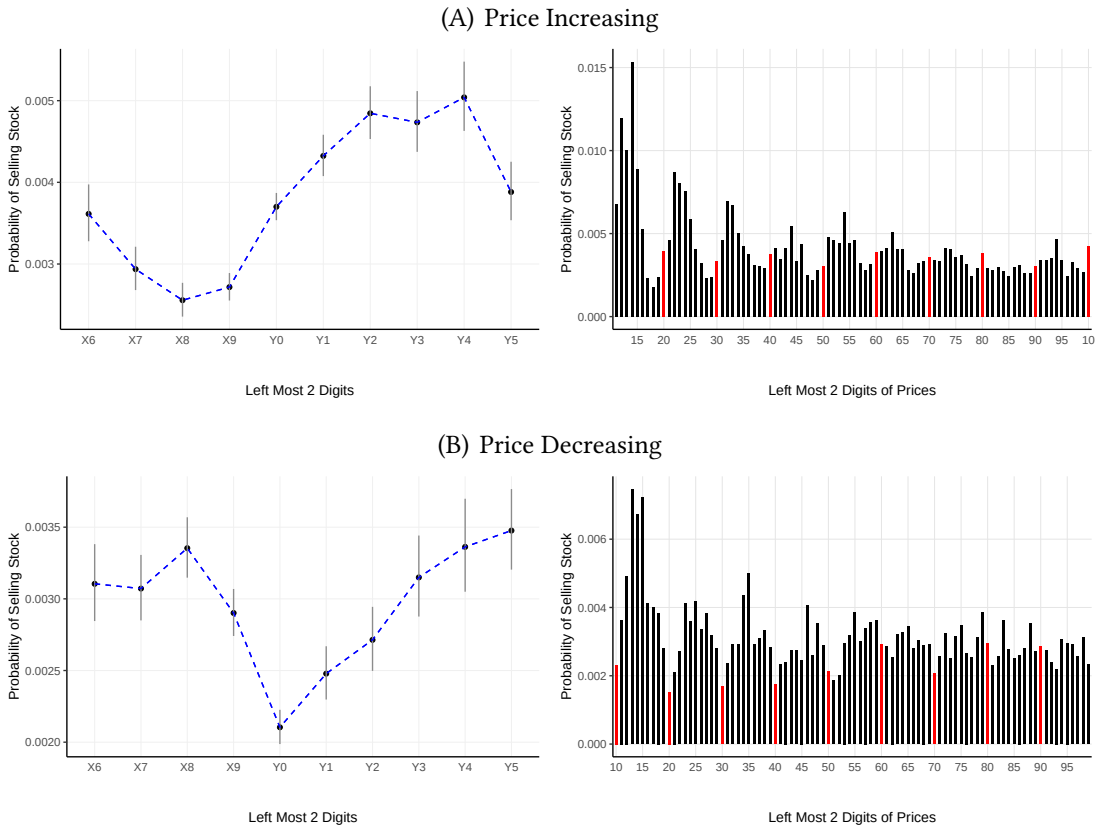
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A9: Leftmost Stock Price Digit and Probability of Sale, Annual Sample
Sell-Price, Login-Days



Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

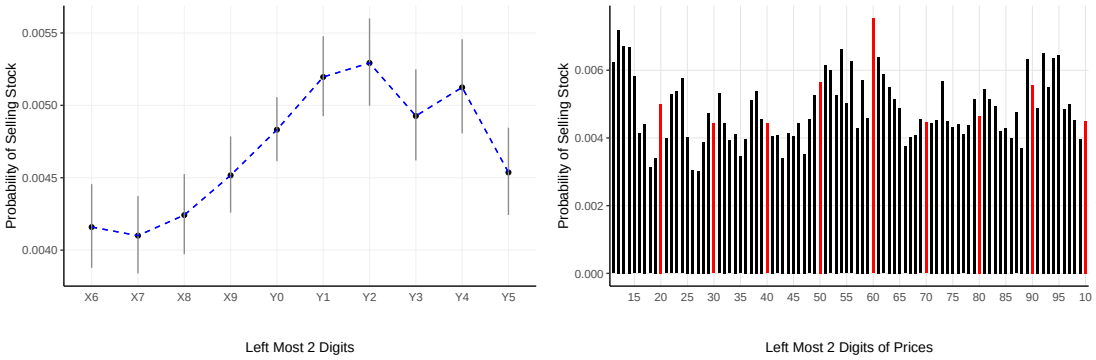
Figure A10: Leftmost Stock Price Digit and Probability of Sale, Monthly Sample
Sell-Price-No-Login-Yesterday, Login-Days



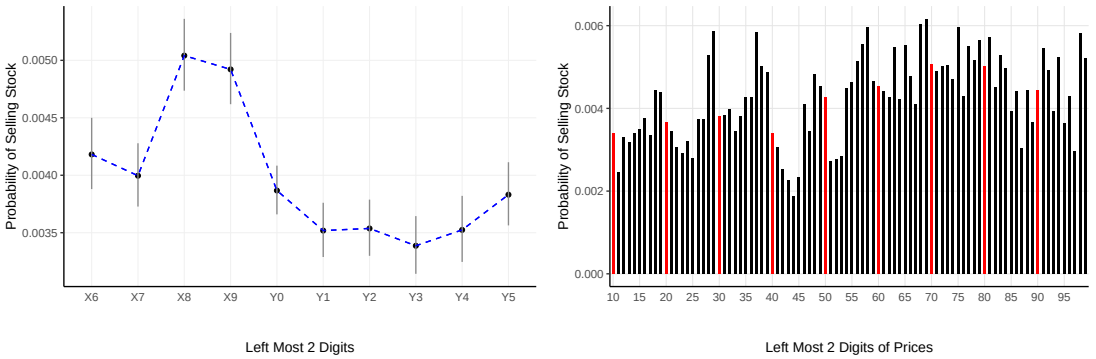
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A11: Leftmost Stock Price Digit and Probability of Sale, Annual Sample
Sell-Price-No-Login-Yesterday, Login-Days

(A) Price Increasing

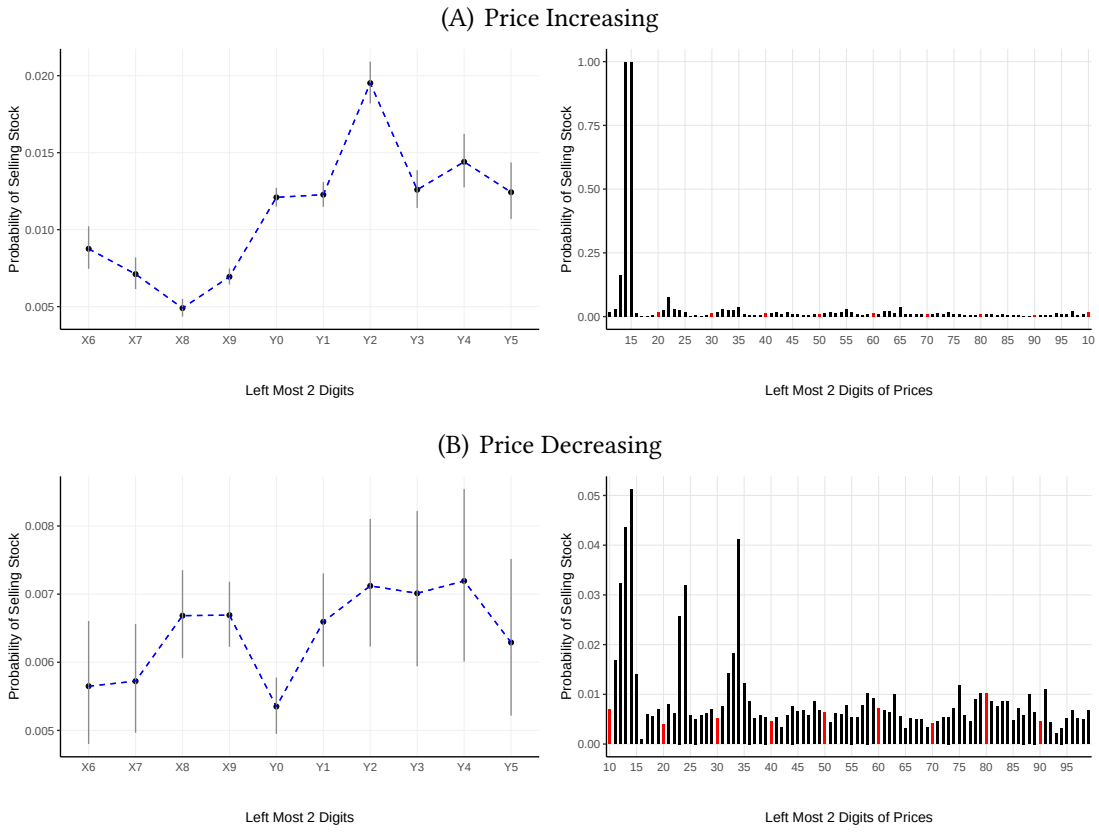


(B) Price Decreasing



Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

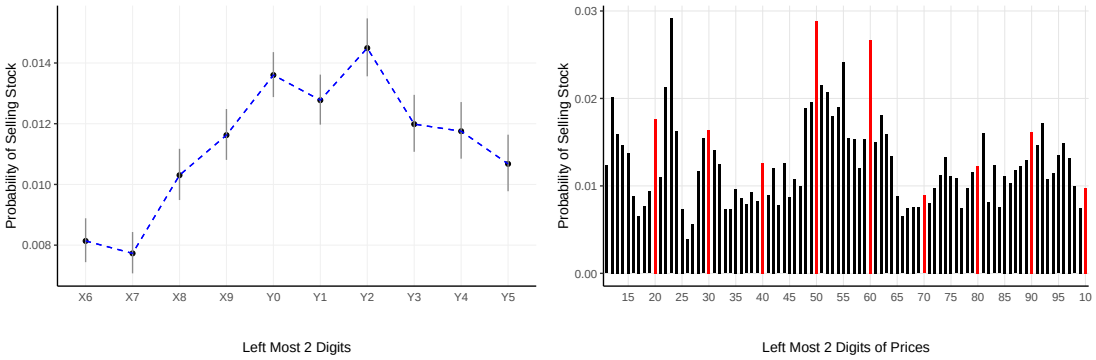
Figure A12: Leftmost Stock Price Digit and Probability of Sale, Monthly Sample
Sell-Price-FTSE100, Login-Days



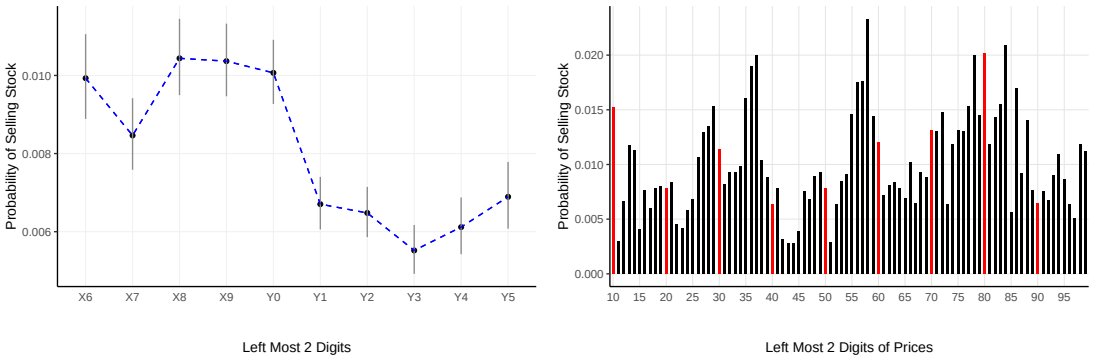
Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

Figure A13: Leftmost Stock Price Digit and Probability of Sale, Annual Sample
Sell-Price-FTSE100, Login-Days

(A) Price Increasing



(B) Price Decreasing



Note: £Y in the X-axes is equivalent to £$X+1$ (e.g., £X9 could include £0.19, £1.9, £19, etc., while £Y0 could include £0.20, £2.0, £20, etc.).

References

Hartzmark, S. M. (2015). The Worst, the Best, Ignoring All the Rest: The Rank Effect and Trading Behavior. *Review of Financial Studies 28*, 1024–1059.

Lacetera, N., D. G. Pope, and J. R. Sydnor (2012). Heuristic thinking and limited attention in the car market. *American Economic Review 102*(5), 2206–36.

Poltrock, S. E. and D. R. Schwartz (1984). Comparative judgments of multidigit numbers. *Journal of Experimental Psychology: Learning, Memory, and Cognition 10*(1), 32.

Shlain, A. S. (2018). More than a penny's worth: Left-digit bias and firm pricing. *manuscript, University of California, Berkeley*.