Pricing with Incomplete information and segmented audiences: How much would you pay for lucky numbers?*

Yingying Elisa Hu†
University of Virginia

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Abstract

This paper investigated how numerological superstition influences pricing dynamics in Hong Kong's license plate market. Our methodology integrated regression analyses to isolate superstition effects and a price discrimination model that explains market segmentation based on superstition levels. Using data from 2024 to 2025 Hong Kong license plate auctions, we analyzed the extent to which culturally symbolic numbers affect consumer valuations, revealing substantial price premiums for numerals or numeral combinations traditionally considered auspicious (e.g., valuation premiums of 64.8% and 42.9% for the numerals '8' and '28,' respectively). We explored market outcomes under both complete and incomplete information scenarios, suggesting optimal governmental pricing strategies for welfare maximization. Combining our menu pricing model and auction data, we discovered that slightly superstitious buyers are willing to pay a premium of 7,286 Hong Kong dollars for a plate with low superstitious appeal, whereas highly superstitious buyers are willing to pay a total premium of 12,623 dollars for a plate with high superstitious appeal.

Keywords: Superstition, Price Discrimination, Adverse Selection, Lucky Number, License Plate

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† Yingying Elisa Hu, elisa.hu@virginia.edu, is a Fourth Year Distinguished Major in the Department of Economics at the University of Virginia, Charlottesville, VA 22904.

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1 Introduction

A license plate can often outprice the car it is mounted on, even for luxury cars such as a Lamborghini. In Hong Kong's 2025 Lunar New Year license plate auction, license plate "88" was sold for 11.4 million Hong Kong dollars[1] (around USD 1.5 million) ("Lunar New Year Auction", 2025). In 2016, the plate "28" was sold at a historic $18.1 million (Ramzy, 2016). At the opposite end of the same auction, an ordinary plate bearing no auspicious digits fetched the statutory reserve of $1,000. Such an 18,000-fold price dispersion is puzzling because, apart from their alphanumeric sequence, Hong Kong license plates are physically identical and confer the same legal right to operate a vehicle. If every buyer only values the functional utility of license plates, assuming they are fully rational, then every license plate would be priced the same.

This stark contrast highlights the powerful influence of behavioral and symbolic values in how people assign worth to otherwise utilitarian objects. Numerals such as "2", "6", and "8" often skyrocket license plate prices way beyond the average value. Why are people willing to pay so much for numbers? What cultural or symbolic meaning gives these numbers such power? How much do they matter to buyers, and how could governments utilize this insight?

Our paper examines the valuation of numerological superstition using the Hong Kong license plate market as a case study. Combining empirical analysis of auction data with theoretical economic modeling, we investigate how numerical preferences influence consumer pricing behaviors and estimate the premiums consumers are willing to pay for goods with higher superstitious appeal. Key findings reveal significant premiums associated with culturally auspicious numbers, particularly "8," "28," "68," and "88." The research also explores differentiated pricing strategies, such as uniform pricing and third-degree price discrimination, which leverage variations in consumers' superstition levels. Limitations include the exclusion of personalized plates and inherent selection biases in auction-derived data.

Prior studies on the valuation of superstition have primarily focused on empirical analyses of how often different numerals appear in commodity prices and how consumers respond to prices containing specific numeral patterns. Consequently, our study contributes significantly to three key areas. First, it incorporates superstitious numeral combinations into existing methodologies for quantifying superstition with broader potential applications beyond

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[1] 1 HKD ≈ 0.13 USD during the years covered by our auction data (2024–2025). All monetary amounts in this paper are denominated in Hong Kong dollars unless otherwise specified.

license plates, such as phone numbers and lottery tickets. Second, it provides deeper insights into valuation mechanisms within the license plate market through a price discrimination model, offering practical strategies for governmental pricing aimed at welfare maximization. Lastly, by integrating price discrimination concepts with empirical analysis, this paper complements a body of literature largely dominated by empirical approaches.

The rest of Section 1 introduces the cultural background of superstition and reviews relevant literature on the valuation of superstition and numerology in the license plate market. Section 2 describes the auction data used in the study. Section 3 outlines the methodology, including our regression analysis, theoretical framework, and how the data is applied to a price discrimination model. Section 4 presents the regression results, focusing on the significance of specific numerals in plate valuation. Section 5 details the assumptions and structure of the price discrimination model, while Section 6 analyzes the model under different levels of information. Section 7 applies the model to Hong Kong auction data and discusses the significance of the results. Section 8 concludes.

1.1 Background Information

Chinese numerology offers a candidate explanation for preferences of certain numbers: in Cantonese, some numerals sound similar to words associated with wealth or misfortune. Table 1 summarizes the canonical mappings. Only one number is unequivocally unlucky—4 (sei ≈ "death"[2]). By contrast, 8 (faat ≈ "prosper"), 6 (luk ≈ "fortune/smooth"), and 9 (gau ≈ "long-lasting") are widely believed to be auspicious, while 1, 2, 3, 5, 7 carry weaker or context-specific connotations. If superstition influences pricing, plates containing lucky digits should command premiums, and those dominated by "4" should sell at a discount.

Table 1.1

Numerals' homophones and connotation in Cantonese

#	Character	Cantonese (Jyutping)	Mandarin (Pinyin)	Cantonese homophone	Meaning / Connotation	Valence
1	一	*jat¹*	*yī*	一 (*jat¹*) "one/whole"	unity, beginning	Neutral
2	二	*ji⁶*	*èr*	易 (*ji⁶*) "easy"	harmony, smooth	Lucky
3	三	*saam¹*	*sān*	生 (*saang¹*) "life"	growth, vitality	Neutral

[2] (Cantonese pronunciation ≈ Cantonese homophone)

4	四	*sei³*	*sì*	死 (*sei²*) "death"	death	Unlucky
5	五	*ng⁵*	*wŭ*	無 (*mou⁴*) "nothing"	emptiness	Neutral
6	六	*luk⁶*	*liù*	祿 (*luk⁶*) "fortune"	good fortune	Lucky
7	七	*cat¹*	*qī*	起 (*hei²*) "rise"	rising, together	Neutral
8	八	*baat³*	*bā*	發 (*faat³*) "prosper"	wealth	**Very lucky**
9	九	*gau²*	*jiŭ*	久 (*gau²*) "long"	longevity	Lucky

Note: The digit "0" lacks an associated meaning beyond being zero in Chinese numerology. While interpretations of numbers vary across sources, there is a broad consensus that "6" and "8" are considered auspicious, while "4" is deemed inauspicious.

1.2 Definition of Superstition

This paper defines superstition as the subjective value assigned to numbers based on cultural associations or symbolic interpretations, independent of the product's functional use. This valuation includes both positive and negative biases, leading individuals to preferentially select or avoid certain numbers. In the context of our study in Hong Kong, superstition manifests as a collective preference for numerals such as "8" and avoidance of numerals such as "4," due to their homophonic similarities to words associated with prosperity and misfortune, respectively. Whether a license plate contains a specific numeral has no effect on the car's eligibility to be driven or on the government's ability to register it. Related concepts explored in other research include numerology, cultural symbolism, and beliefs surrounding auspicious ("lucky") and inauspicious ("unlucky") numbers.

1.3 Literature Review

Prior research on the valuation of numerological superstition has primarily focused on empirical models, with a smaller number of experimental and theoretical studies. Yang (2010), for example, analyzed the frequency of numerals in the prices of consumer goods in the Beijing area. He found that "lucky" numbers such as 6, 8, and 9 appeared more frequently on price tags, while "unlucky" numbers like 4 and 7 occurred far below average occurrence.

Unlike Yang's seller-oriented approach, which examines the frequency of auspicious digits in product listings, many studies have explored how consumers select certain numerals over others. These empirical analyses span several markets, including housing, lottery, and license plates. He et al. (2020), for instance, conducted an ordinary least squares (OLS) regression analysis on the Singapore housing market and found that homes with addresses ending in lucky numbers commanded price premiums. Similarly, Bourassa and Peng (1999) applied a hedonic pricing model to Chinese neighborhoods in New Zealand and found that houses with auspicious numbers were valued more highly.

Lottery-based studies further illustrate numerological preferences. Otekunrin et al. (2021) found that Nigerian lottery participants favored repeated digits such as “88,” while Polin et al. (2021) showed that Israeli players tended to select extreme numbers like “1” or “90.” In contrast, Wang et al. (2016) observed that Dutch participants preferred numbers located near the center of the choice form.

Woo and Kwok (1994) and Ng et al. (2010) are the two major prior studies on the value of numerological superstition in the Hong Kong license plate market. Both ran regressions of numeral counts on plate prices, with the latter study analyzing how different economic conditions and plate types influence pricing.

Experimental papers on numerology focused on presenting different pricing bundles to consumers and examining their willingness to pay. Gendall et al. (1997) estimated the demand curve of snacks with odd price points, pricing at 9.99 instead of 10,00 increases purchase probability, but 9.99 and 9.95 have no significant difference in purchase probability. While Gendall presented mental discounting of price, Block and Kramer (2009) explored the role of auspicious numbers, finding that Taiwanese consumers preferred products packaged in “lucky” quantities, such as 8 tennis balls instead of 10.

Theoretical studies on superstition remain limited, especially in relation to economic valuation. Fudenberg and Levine (2006) used game theory to demonstrate that superstitions located far from the equilibrium path are more likely to persist. While their study presents a valuable approach to the study of superstition, it focuses on tribal beliefs—a type of superstition distinct from numerology. Furthermore, Torgler (2007) hypothesized that superstition formed a component of religious beliefs in former Communist countries, providing a potential explanation for the origins of superstition but leaving questions about its economic valuation unanswered. Meanwhile, empirical studies span a range of cultural contexts—including Nigeria, Singapore, China, Italy, and the Netherlands—demonstrating that superstition is a globally relevant phenomenon.

In addition to studies on superstition, this paper also relates to broader research on license plates, particularly in the context of social signaling. For example, Butler (2020) analyzed license plate trading in Delaware and used plate number length as an instrument for status signaling to estimate the premium consumers pay for perceived social status.

2 Data

In this section, we provide a detailed overview of our data, the strengths and weaknesses of using this data, data dictionary, and descriptive statistics.

2.1 Data Source

This study used auction results for traditional vehicle registration marks (license plates) from May 2024 to April 2025, sourced from the Hong Kong Transport Department website, which was the same dataset deployed by Ng et al. (2020). The dataset covered 7 auctions and includes 1,619 license plates, spanning both in-person and online formats. Of these, 552 plates were unsold, leaving 1,067 valid observations for analysis. The first five auctions were conducted in-person using English ascending auctions, while the last two were online sealed-bid auctions (HK Transport Department, 2025).

Hong Kong license plates are categorized into two types: traditional and personalized. Traditional plates follow a strict, standardized format, consisting of a two-letter prefix (or no prefix) followed by a number between 1 and 9999. In contrast, personalized plates allow for any combination of letters, numbers, and spaces, and can even be displayed across two lines, as long as the total length does not exceed eight characters.

Personalized license plates allow car owners to deliver English messages such as “ARE U OK,” “I AM CAR,” or “NUMBER1” (Dicker, 2023). Since these plates can extend from one line to two, some plates even display emojis or visual figures, such as “$\substack{O\ \ O \\ U}$” or “$\substack{U\ \ U \\ V}$” (HKnumberplates, 2022). Personalized license plates often carry value in creative expression, which requires familiarity with linguistic trends, syntax, and cultural references—areas that lie beyond the scope of this study on numerical superstition. Therefore, this paper focuses exclusively on traditional license plates to control for non-numerical factors that may influence valuation.

2.2 Strengths

The Hong Kong license plate market serves as a powerful tool for studying the non-material value associated with numbers via superstition or cultural symbolism. This is due to three key factors: the standardized design of the plates, which removes aesthetic variation as a pricing factor; a local population with deeply rooted beliefs in auspicious and inauspicious numbers; and the availability of open-access, government-compiled vehicle registration and auction records.

Regulatory standardization

Hong Kong standardized its license plate format in arrangement, form, font, size, and spacing of letters and numerals, as well as the display of the plates in terms of colors, construction, fitting, and illumination. All Hong Kong license plates should be displayed as black letters and numerals upon a white background on the front of a vehicle, and black letters and numerals upon a yellow background on the back of a vehicle (Legislation, 2012). Appendix A provides a sample image of a license plate. This standardization controls the variance of aesthetic preference in license plate valuation, allowing a better estimation of superstitious valuation.

Pervasive numerological beliefs

Additionally, the majority of the Hong Kong population is immersed in the Cantonese culture. In Chinese or Cantonese culture, numbers carry superstitious values because they are homophones to auspicious words in Cantonese, as explained in the introduction. This strong cultural connection makes numerological beliefs particularly salient among Hong Kong consumers (Liu 2024), providing a sound basis for hypothesizing higher valuations for license plates containing numbers such as “2,” “6,” “8,” and combinations like “28.”

Public, transaction-level data

Public, Transaction-Level Data The Hong Kong government has consistently provided comprehensive, publicly accessible datasets through the Annual Transport Digest since 1999 and detailed auction listings beginning in May 2024. This extensive panel data includes complete records of the license plate market and transaction-level observations, offering a robust foundation for empirical analyses of numerological influences on market valuations.

2.3 Weaknesses

Selection bias and limitation

The auctioned license plates are not representative of the general license plate market in Hong Kong. We assume that only license plates that have been determined valuable enough, by whoever holds authority over their distribution, have been selected for auction. Hence, the findings of this paper may be limited in their generalizability to the broader population of license plates in circulation. Nevertheless, we expect the relative superstitious values of specific numbers to remain consistent between the auctioned plates and the typical license plate.

Additionally, since our sample includes both English ascending and sealed-bid auction formats, the observed winning prices may reflect systematic differences in bidding behavior across formats rather than underlying valuations. Nevertheless, our study will include an auction-date fixed effect in all regressions to absorb any format-driven shifts in the bid distribution, ensuring that our model estimation captures variation within, rather than between, auction mechanisms.

2.4 Data Dictionary

Table 2.1 gives a full data dictionary for all the variables used in this study, including their types, units (or formats), and coding conventions. All binary pattern-flags (e.g., aa, abc) and letter-pattern variables (e.g., no_letter) are coded 0 = absent/FALSE, 1 = present/TRUE. The date variable is recorded as a categorical factor in MM/DD/YYYY format, and Price_clean is the final hammer price in Hong Kong dollars.

Table 2.1 Data Dictionary

Variable	Variable name	Measurement unit	Allowed values	Description
Letter prefix	Letters	Character	A–Z; or NA	Alphabetic prefix of the registration mark
Plate numeral	Numbers	Character	“0”–“9999”	Numeral part of the plate, stored as a string (1–4 digits)
Auction date	Date	Factor	"05/12/2025" "11/16/2024" "12/01/2024" "12/07/2024" "3/20/2025" "2/20/2025" "2025-04-14"	Date when the plate was sold
Cleaned auction price	Price_clean	Integer	1000–285000	Final auction price in Hong Kong dollars
Digit count	digit_count	Integer	(1,2,3,4)	Number of digits in the

Numeral occurrence counts	num_0, num_1, num_2, num_3, num_4, num_5, num_6, num_7, num_8, num_9	Integer	(0,1,2,3,4)	Count of each respective numeral (0–9) in the plate's numeral string
Numeral combinations	has_28, has_68, has_88	Integer (binary)	(0,1) 0 = combination absent; 1 = combination present	Presence of the respective numeral combination
Numeric-patterns	aa, aaa, aaaa, aabb, abab, abc, cba, abac, baca, ba, hundreds, thousands, symmetric	Logical	(0,1) 0 = FALSE = pattern absent; 1 = TRUE = pattern present	Flags for various patterns detected in the numerals
Letter-patterns	letter_aa, no_letters, no_pattern_letter	Logical	(0,1) 0 = FALSE = pattern absent; 1 = TRUE = pattern present	Flags for patterns (or absence of letters) in the alphabetic prefix

2.5 Descriptive Statistics

Price Variation

Figure 2.1 presents the distribution of license plate prices based on $\log_{10}$ transformation to visualize the range of license plate prices. The distribution is markedly right-skewed but unimodal. Most observations lie between $\log_{10}(Price)$ = 3.3 and 4.0 (≈ $2,000 ~ 10,000), with the modal bin centered around 3.6 (≈ $4,000). Density declines smoothly beyond $\log_{10}(Price)$ = 4.2 and tapers into a long upper tail extending past 5.0 (above ≈ $100,000). The log transformation compresses this extreme tail, allowing the main mass of the data to be visualized clearly and justifying its use in subsequent regression models.

Figure 2.1 shows the cumulative distribution of license plate prices, illustrating the concentration of market value among plates. The dashed 45-degree line represents perfect equality, where every license plate would contribute equally to the total value. The curve lies significantly below the line of equality, indicating substantial concentration: a small fraction of license plates accounts for a disproportionately large share of total market value. The steep rise near the right edge of the curve suggests that the most expensive plates dominate the overall market value. This pattern highlights the inequality in license plate prices, with a few highly valued plates skewing the distribution. Given that the auction data is positively biased toward selecting higher-value plates, the full Hong Kong license plate market may exhibit less extreme inequality than what Figure 2.2 suggests.

Figure 2.1. Histogram with kernel-density overlay of $log_{10}(Price)$

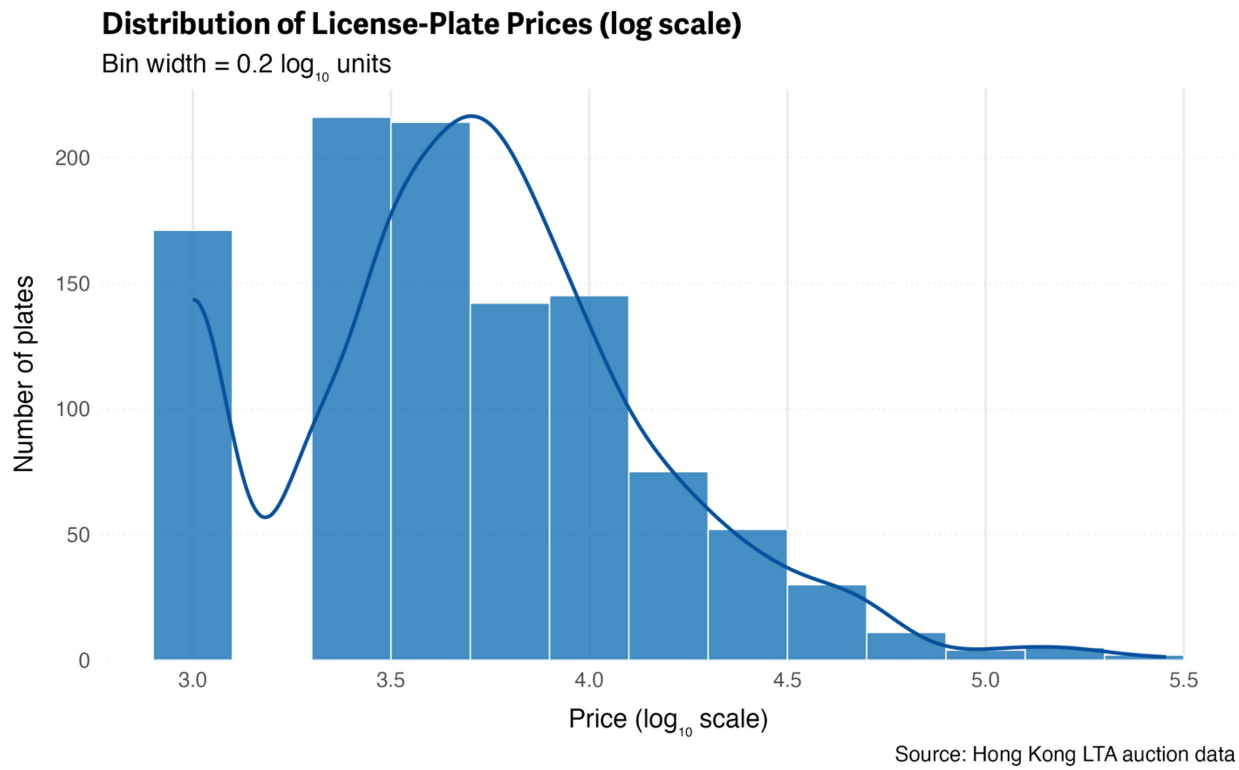
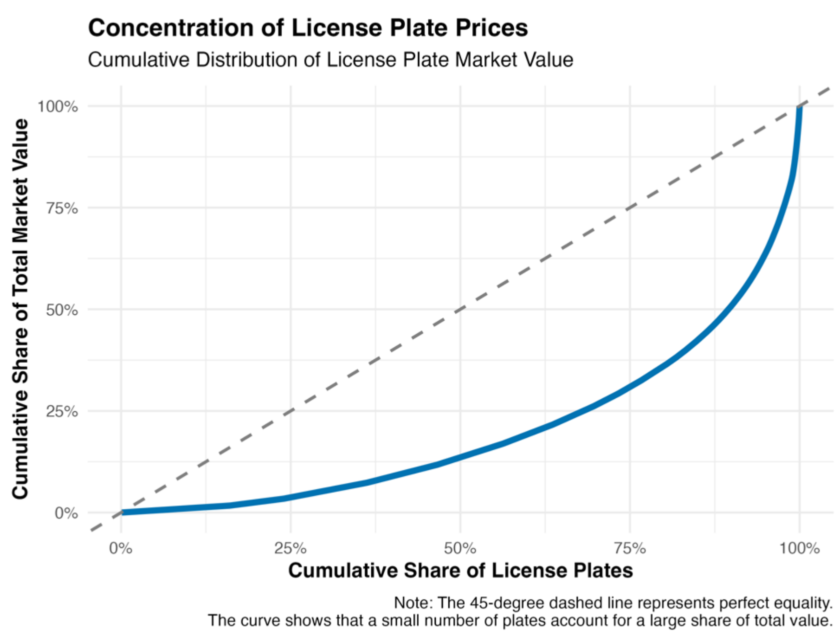


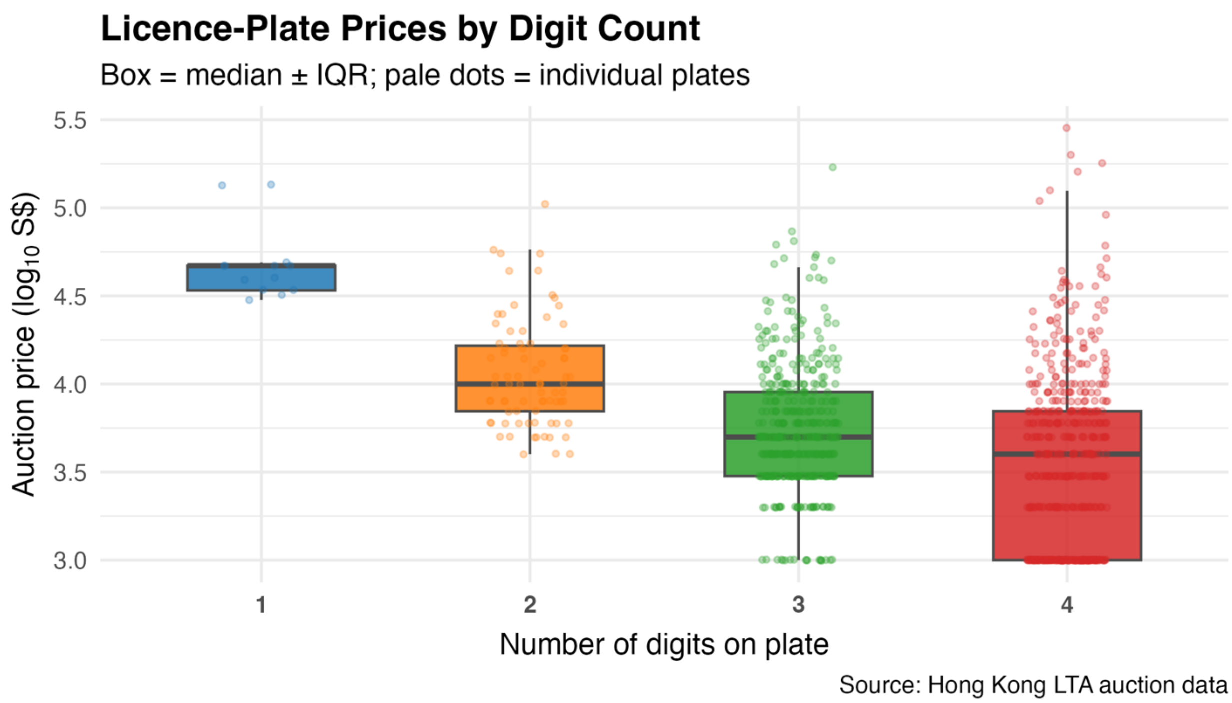
Figure 2.2 Cumulative Distribution of License Plate Market Value



Both Figure 2.1 and Figure 2.2 illustrate the importance of using log transformation in our empirical regression and present the importance of studying the reasons driving the price inequality.

Price Variation Based on Digit Count

Figure 2.3 Auction prices by license-plate digit count ($\log_{10}$ scale)

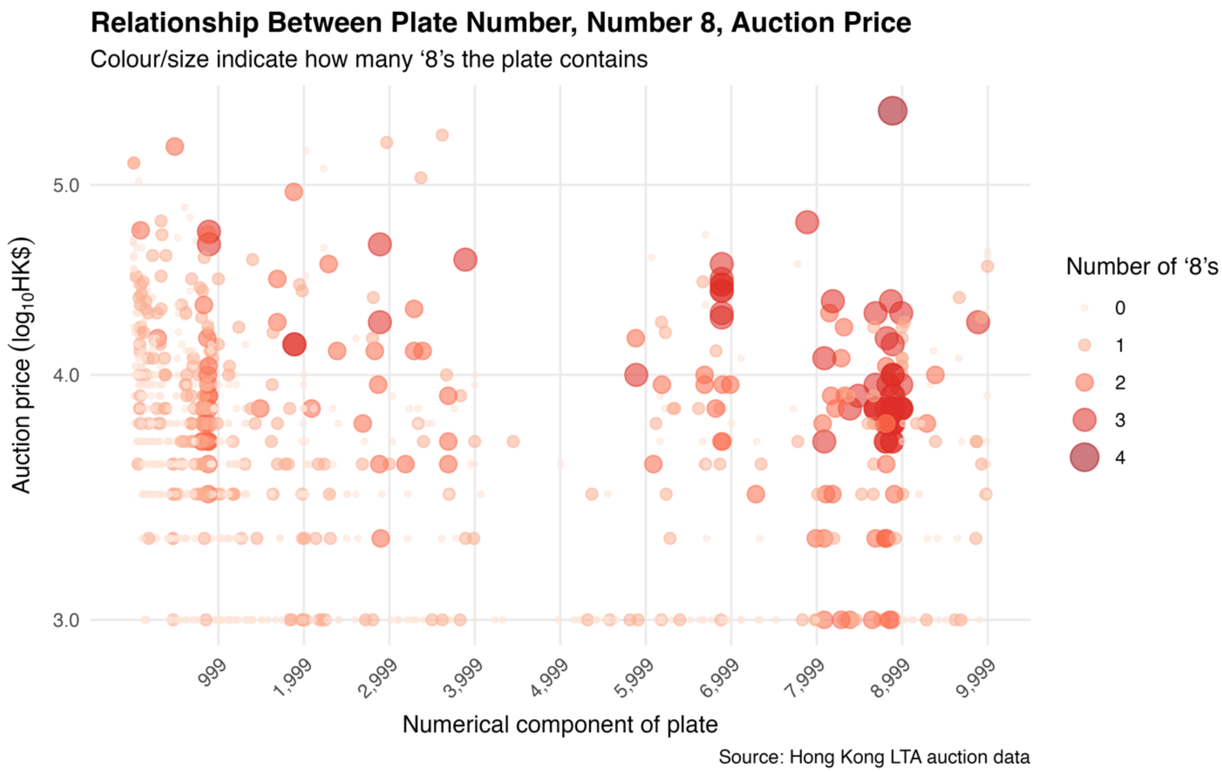


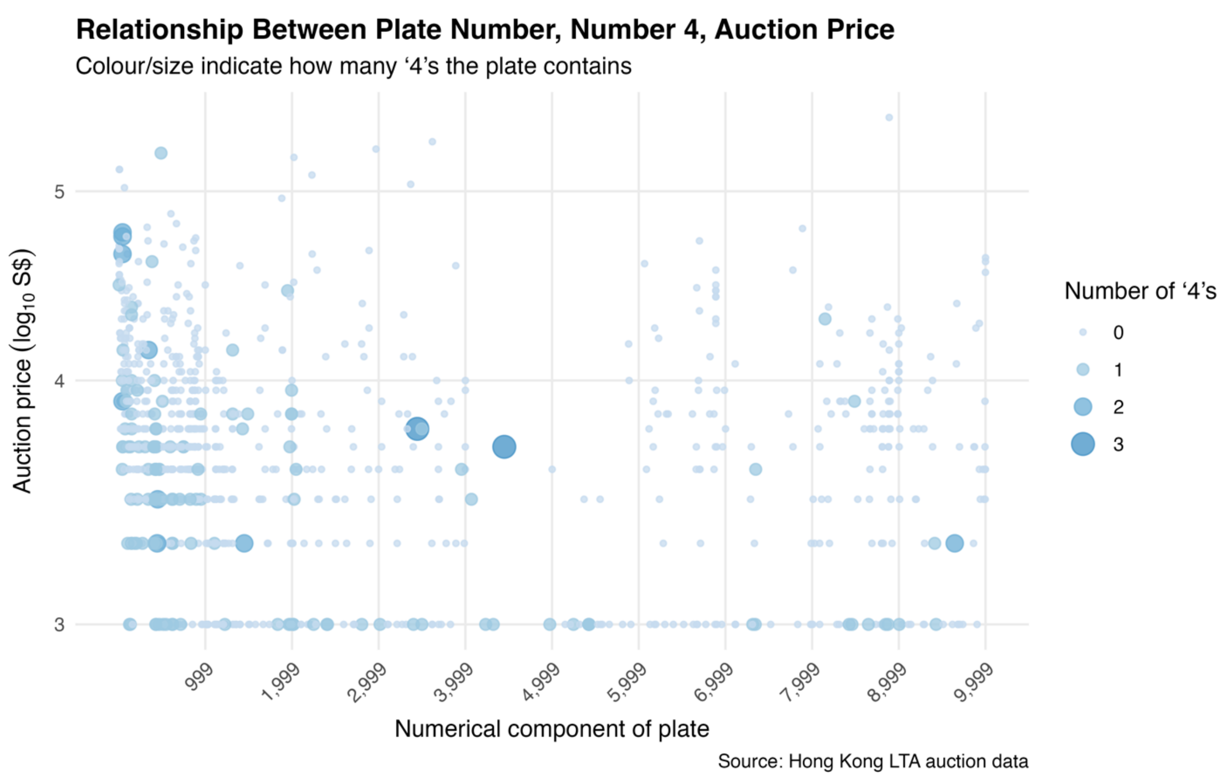
Note. The figure plots the distribution of transaction prices, in logarithms, for plates containing one to four numerical digits.

Our data presents consistency with Butler's study on Delaware license plates that license plates with shorter numeral digits have higher transaction prices. Figure 2.3 illustrates the median, standard deviation, and individual observations of $\log_{10}$ transformed license plate price based on digit count. The data presents a monotonic decline in median price and diminishing price dispersion with a narrower inter-quartile range moving from four-digit plates to one-digit plates. Given the importance of digit count on the final price, our study controls the model with digit count.

"Lucky" 8 and "Unlucky" 4

Figure 2.4 $\log_{10}$ of auction prices with plate number and occurrences of 8s (top) and 4s (bottom)





In general, plates with more 8s correspond to higher prices, as shown by the upward trend of darker, larger red bubbles in *Figure 2.4* (top). Plates containing multiple “8”s naturally cluster around the 8000s, as these numbers inherently include at least one '8'. Within this 8000-8999 range, plates with more than one “8” appear to command lower prices than similarly composed plates outside the 8000s. This is evident from *Figure 2.4*, where larger and darker bubbles—indicating more 8s—tend to sit lower on the y-axis in the 8000s compared to elsewhere. Despite this, the 8000s range overall still commands a higher median price ($7,000) than other 4-digit plates ($3,000). Expectedly, '8888' is the most valued plate at $285,000.

The number “4” is generally less popular in the auctions, especially when compared to the auspicious number “8.” This is reflected in *Figure 2.4* (bottom) by the prevalence of smaller and lighter blue bubbles associated with a lack of 4s. However, there's a noticeable concentration of high-value plates with multiple “4”s in the 0–999 range. This suggests that the premium associated with low-digit plates may offset the negative cultural connotations of the number “4,” making these combinations more valuable than similar plates in the 4-digit range.

Frequency Analysis

Table 2.2 Frequency of presence of each numeral

Digit Count	**Plates Sold**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
1	13	0 (0.0 %)	0 (0.0%)	1 (7.7%)	1 (7.7.%)	2 (15.4%)	4 (30.8%)	3 (23.1%)	2 (15.4%)	0 (0.0%)	0 (0.0%)
2	79	11 (13.9%)	17 (21.5%)	9 (11.4%)	14 (17.7%)	7 (8.9%)	24 (30.4%)	13 (16.5%)	16 (20.3%)	25 (31.6%)	7 (8.9 %)
3	446	173 (38.8%)	162 (36.3%)	113 (25.3%)	82 (18.4%)	82 (18.4%)	133 (29.8%)	97 (21.7%)	148 (33.2%)	97 (21.7%)	103 (23.1%)
4	529	265 (50.1%)	194 (36.7%)	163 (30.8%)	52 (9.8%)	65 (12.3%)	152 (28.7%)	88 (16.6%)	248 (46.9%)	183 (34.6%)	142 (26.8%)
Total	**1067**	449 (42.1%)	373 (35.0%)	286 (26.8%)	149 (13.9%)	156 (14.6%)	313 (29.3%)	201 (18.8%)	414 (38.8%)	305 (28.6%)	252 (23.6%)

The numeral “1” appears most frequently across auctioned license plates, with the highest occurrence in both 4-digit plates (50.1%) and 3-digit plates (38.8%), resulting in the highest overall occurrence at 42.1%. The numeral “8” ranks second overall (38.8%), with the second-highest presence in 4-digit plates (46.9%) and third-highest in 3-digit plates (33.2%). The numeral “2” follows with an overall occurrence of 35.0%, ranking third in 4-digit plates (36.7%) and second in 3-digit plates (36.3%).

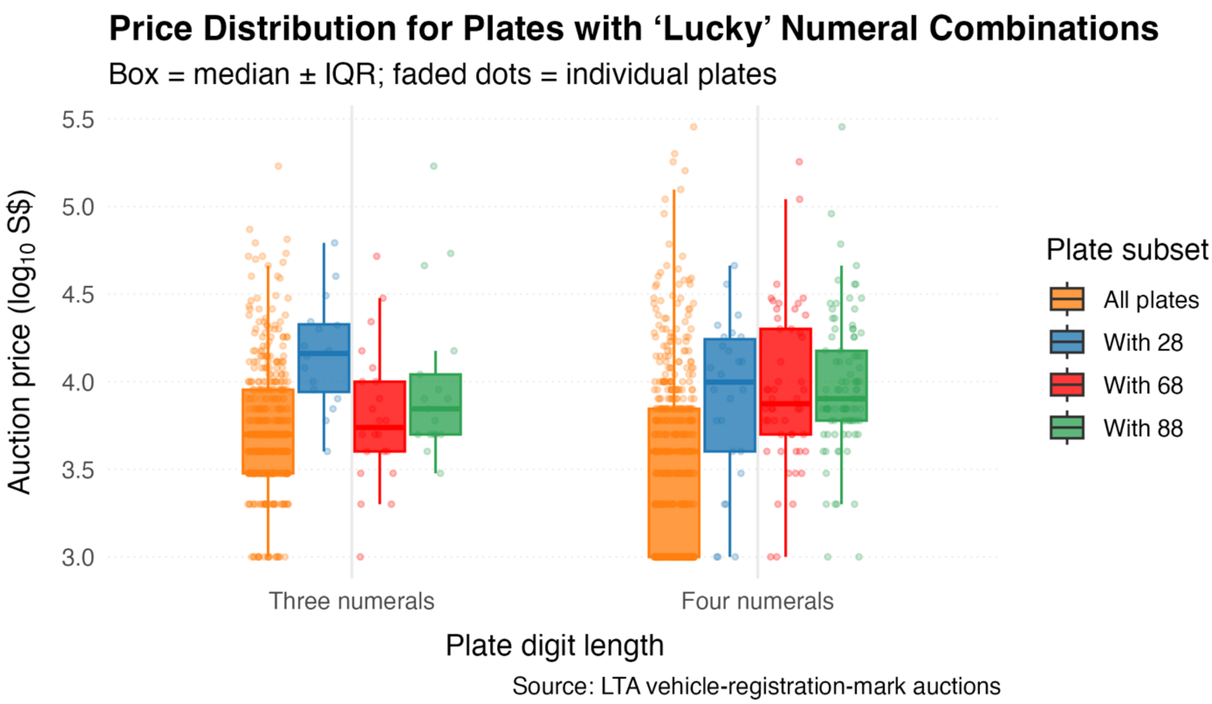
Despite being considered numerologically neutral in Cantonese culture, the prominence of “1” suggests it may function as an inoffensive, visually balanced “filler” digit, often used to complement more auspicious numbers like “8” or “2.” The numeral “4” appears least frequently across all auctioned license plates, reflecting a selection bias toward fewer inauspicious numbers in auctions.

“Lucky” Numeral Combinations 28, 68, and 88

Numeral combinations could carry superstitious values beyond the combination of individual numerals. See Figure 2.5 for both digit lengths, the median price of plates bearing *any* of the lucky pairs exceeds the corresponding benchmark median. The premium is largest for the 88 combination: roughly 0.25–0.30 log-points (≈ 30 % higher in levels) relative to the full three-digit sample and ≈ 0.20 log-points for the four-digit sample. Plates with 68 trade at a slightly smaller premium, while 28 sit between 68 and 88.

These visual patterns motivate the inclusion of dummy variables for *28*, *68,* and *88* (and their interactions with digit length) in the hedonic regressions that follow. The sizeable and persistent gaps suggest that superstition-related digits capture price variation beyond conventional scarcity proxies such as digit count or palindromic patterns.

*Figure 2.*5 Price Distribution for Plates with “Lucky” Numeral Combinations



Note. The figure plots $\log_{10}$-prices for three- and four-digit licence plates. The orange boxes (labeled All plates) represent the full benchmark sample, while the blue, red, and green boxes isolate plates whose numerical strings contain the auspicious pairs 28, 68, and 88, respectively. Within each digit-length column, the boxes are position-dodged so that distributions are directly comparable on a common vertical scale.

Count of Letter and Numeral Patterns

Table 2.3 expands from the data dictionary and provides a summary of the letter and numeral patterns used in the model, including their variable names, frequencies, descriptions, and illustrative examples.

Table 2.3 Variable names, count, description, and example of patterns used in the model.

Pattern (Variable Names)	Count	Description	Example
Special digit substrings			
has28	42	Contains the consecutive digits “28”	AB 928
has68	73	Contains the consecutive digits “68”	AB 1687
has128	2	Contains the consecutive digits “128”	AB 7128
has88	112	Contains the consecutive digits “88”	AB 988

Repeating digits			
aaaa	4	Four identical digits	AB 1111
aaa	91	Three identical digits	AB 1112
aa	339	Two identical digits, excluding “88”	AB 1123
Alternating / block repeats			
abab	7	Alternating digit pair	AB 1515
aabb	9	Double-repeat block	AB 1122
abac	36	Alternating with interposed digit	AB 1417
baca	19	Alternating with interposed digit	AB 4171
Palindromes			
Symmetric	67	Reads the same forwards and backwards, excluding “aaaa” pattern	AB 2002
Sequential – ascending			
abcd	0	Four-digit strictly ascending sequence	AB 1234
abc	11	Three-digit strictly ascending sequence	AB 123
ab	365	Two-digit strictly ascending sequence	AB 12
Sequential – descending			
dcba	2	Four-digit strictly descending sequence	AB 4321
cba	11	Three-digit strictly descending sequence	AB 321
ba	181	Two-digit strictly descending sequence	AB 21
Round numbers			
Hundreds	10	Ends with “00,” excluding “000”	AB 4100
Thousands	2	Ends with “000”	AB 4000
No identified numeral pattern	333	Does not match any numeric pattern above	AB 1028
Letter patterns			
Two same letters	195	First two letters are identical	AA 1028
Plates without letters	7	Numeric-only plates	1928
No letter pattern	872	Does not match any letter pattern above	AB 1234

3 Methodology

Pattern Identification, Digit Substrings, and Variable Creation

The auctioned plates were assigned variables that describe their lengths, notable letter or numerical patterns, and presence of numeral combinations. A total of 20 pattern types describing the letters and numbers of the plates were identified and non-exclusively assigned to each plate. For the presence of digit substrings, we identified the presence of all one- to three-digit strings ranging from 1 to 999 within each plate. For example, the plate HX7899 would contain the strings 7, 8, 9, 78, 89, 99, 789, and 899. This matrix of digit string presence was used in further analysis to identify significant digit combinations that could influence license plate value, either by inflating or deflating it. While we had already identified a few candidate number strings based on previous literature on numerology, this method allowed us to capture additional significant number strings. All variable creation and assignment were performed in R (2023), and date visualizations are created with the ggplot2 package (Wickham 2016).

Regression

We used linear regression to predict license plate prices based on their letters and numbers. To isolate the effect of specific numerals, we first controlled for plate length, which has been shown to significantly influence license plate value in Butler (2020) and our descriptive statistics section. We then extended the regression model from Ng et al. (2010) by controlling for numeral patterns and letter patterns that are observed in our data observations, defining each control variable with a clear order of application and including numeral combinations such as "88" as variables of interest.

Using indicator variables that count the occurrence of each numeral (num_0 to num_9) simultaneously can introduce strong multicollinearity due to the dummy variable trap. For example, if a plate has a count of zero for num_0 to num_8, then num_9 must be greater than zero, leading to perfect prediction. To address this, we iteratively dropped and re-included certain variables while assessing model performance, ensuring that the specification remained both theoretically sound and consistent with real-world observations. Ultimately, we excluded num_0 (the count of the numeral "0") because the number "0" holds a neutral meaning in Cantonese culture, lacking strong auspicious or inauspicious connotations, making it a suitable reference category.

Note that the variable "aa," which captures the pattern of two identical digits in a license plate, includes all such patterns except "88." This is because all plates with the "88" pattern would also be counted under "aa," leading to overlapping effects and potential multicollinearity. Similarly, the "symmetric" variable excludes plates that follow the "aaaa" pattern, which is captured separately.

The regression model takes the following form,

$$ln(Price) = \alpha + \beta(\text{number counts of each numeral}) + \kappa(\text{special numeral combinations})$$

$$+\gamma(digit\ count)\ + \delta\ (numeral\ patterns)\ + \lambda\ (letter\ patterns) + \varepsilon$$

The notations β, δ, and λ are vectors. The model includes variables that count the frequency of each numeral in a license plate,

$$\beta\ (number\ counts\ of\ each\ numeral) = \beta_1(\text{num\_1}) + \beta_2(\text{num\_2}) + \beta_3(\text{num\_3}) + \beta_4(\text{num\_4})$$

$$+ \beta_5(\text{num\_5}) + \beta_6(\text{num\_6}) + \beta_7(\text{num\_7}) + \beta_8(\text{num\_8}) + \beta_9(\text{num\_9})$$

This measures how the increase in the presence of a specific number changes the final valuation of the license plate. Noted that num_0 is dropped as a reference point for the measurement of relative effects of other numerals on license plate prices. The model also contains variables with special numeral combinations "68," "28," and "88" given the significant increase in price associated with license plates of those numbers, as shown in Figure 2.5,

$$\kappa(\text{special numeral combinations}) = \kappa_1(\text{has\_28}) + \kappa_1(\text{has\_68}) + \kappa_1(\text{has\_88})$$

$(digit\ count)$ is a discrete numerical variable that measures the number of numerals (1 to 4 digits) on a license plate, capturing the effect of plate length on valuation.

$(numeral\ patterns)$ and $(letter\ patterns)$ includes all the patterns listed in Table 2 except for 4-digit ascending (abcd), descending (dcba), and "has_128" due to a lack of valid observations with those attributes.

Theoretical Modelling

Our theoretical model employed economic theory, particularly price discrimination and adverse selection models, to examine how numerological superstition influences consumer valuation of Hong Kong license plates. We explored models based on varying levels of information availability, complete and incomplete, to provide insights into market behaviors and governmental pricing strategies. We outlined our approach to modeling consumer behavior and pricing strategies by governments acting as monopolists in this unique market.

Applying Model to Data

Based on the results of our regression model, we identified license plates containing “8,” “28,” or “68” as having high superstitious appeal. We then applied the pricing framework from our theoretical model, which offers two bundles, each with a different combination of price and superstitious appeal, allowing consumers to self-select the option that best matches their preferences. By combining this model with actual auction data from Hong Kong, we estimated the premium consumers are willing to pay for plates based on the level of superstitiousness of individuals.

4 Empirical Results and Discussion

Table 3 presents the four final iterations of the regression model in order of increasing specificity, each incorporating a greater number of predictor variables and control variables. Each model regresses the natural logarithm of the final auction price on plate length (digit_count), specific digit strings (e.g., has_28), the occurrence counts of each digit in the plate (e.g., num_1), numeral patterns, and alphabetic patterns, with auction-date fixed effects. Given the large number of variables, only the key variables of interest are reported in Table 4.1. The full regression output is provided in Appendix B.

The following empirical results and discussion build on regression model (4) in the last column.

Table 4.1 Numeral Count Regression Results, Controlling Numeral and Letter Pattern

Numeral Count Regression Results, Controlling Numeral and Letter Pattern

	Dependent variable:			
	log(Price_clean)			
	(1)	(2)	(3)	(4)
num_1	0.202***	0.197***	0.183**	0.229***
	(0.058)	(0.058)	(0.080)	(0.061)
num_2	0.310***	0.269***	0.246***	0.190***
	(0.063)	(0.064)	(0.092)	(0.071)
num_3	0.338***	0.332***	0.260***	0.183***
	(0.063)	(0.063)	(0.082)	(0.064)
num_4	-0.109	-0.121	-0.017	-0.045
	(0.078)	(0.078)	(0.115)	(0.088)
num_5	-0.103	-0.115	-0.235**	-0.126

	(0.077)	(0.077)	(0.101)	(0.078)
num_6	0.321***	0.298***	0.232***	0.184***
	(0.060)	(0.062)	(0.084)	(0.065)
num_7	-0.018	-0.016	-0.065	-0.074
	(0.070)	(0.070)	(0.093)	(0.072)
num_8	0.688***	0.525***	0.480***	0.500***
	(0.055)	(0.069)	(0.092)	(0.071)
num_9	0.332***	0.330***	0.253***	0.282***
	(0.059)	(0.059)	(0.098)	(0.076)
has_28		0.428***	0.441**	0.357***
		(0.139)	(0.176)	(0.136)
has_68		0.218*	0.480***	0.346***
		(0.113)	(0.137)	(0.106)
has_88		0.408***	0.259	0.318**
		(0.134)	(0.169)	(0.130)
Date Fixed Effects:	X	X	X	X
Digit count controlled:	X	X	X	X
Numeral combos controlled:		X	X	X
Numeral patterns controlled:			X	X
Letter patterns controlled:				X
Observations	1,067	1,067	548	548
R^2	0.411	0.421	0.607	0.769
Adjusted R^2	0.402	0.410	0.582	0.753
Residual Std. Error	0.812 (df = 1050)	0.806 (df = 1047)	0.771 (df = 514)	0.593 (df = 512)
Note:	*p<0.1; **p<0.05; ***p<0.01			
	Two-tailed p-value. Standard errors in parentheses.			

Numerals

Of all the digits, the number of "8"s has the strongest positive correlation with the price of a license plate. Inserting a single "8" in place of a neutral digit raises the expected license plate price to $e^{0.500}$ = 1.648 of the original price, an increase of 64.8 percent. The number of "9"s also presents strong positive correlation with plate valuation. Replacing a neutral digit with "9" increases the final plate price by around 32.6 percent ($e^{0.282} = 1.326 - 1$).

The rest of the auspicious digits, "2" and "6" similarly have positive effects on license plate valuation, yielding a 20.9 percent and 20.2 percent premium, respectively, over a neutral number.

The numeral "1" as a culturally neutral number presents a high premium of 25.7 percent. The social signaling value of "1" symbolizing being number one could potentially explain the premium value behind it.

Culturally unlucky numeral "4" does not present a statistically significant result, which could be explained by the selection bias of the data. Since more premium license plates are selected to be auctioned, the inauspicious numeral "4" has a lower chance of appearing in the data and only appears when coexisting with other auspicious numerals or premium number combinations (e.g., symmetric HH 444). The numeral "4" appears in 14.0% of all license plates sold, whereas the numeral "8" appears in 38.8% and the numeral "2" appears in 35.0% of the sold plates.

Digit strings

The number combinations "28," "68," and "88" command significantly higher premiums than would be expected from the combined effects of their individual digits. For instance, "28" yields a 42.9 percent premium over the combined contributions of "2" and "8," "68" generates a 42.3 percent premium, and "88" generates a 37.4 percent premium.

We theorize that these elevated valuations stem from the lexical meanings formed when the digits are combined. For example, "28" (易發, meaning "easy to prosper") and "68" (祿發, meaning "fortune and prosperity") derive added appeal in a culturally superstitious context. The double "8" may symbolize "double or exponential prosperity."

However, it is also possible that a non-lexical compounding effect is at play, whereby the proximity of auspicious digits amplifies their overall value beyond linguistic interpretation. This effect could arise from the perceived rarity or visual impact of such combinations, independent of their lexical meaning. Ultimately, whether the premium of digit strings arises from lexical meaning or another compounding mechanism, the value is rooted in the superstitious significance of the individual numbers "2" and "8." Moreover, attempting to isolate and control for lexical effects is inherently challenging, as Cantonese numerology is itself fundamentally lexical, even when interpreting single digits.

Nevertheless, the evidence supports the conclusion that numeric superstition contributes to consumers' willingness to pay for Hong Kong registration marks. These findings highlight how cultural beliefs can translate into quantifiable market behavior and how a well-designed auction system can capture a significant share of the resulting surplus.

5 Theoretical Model

We will introduce the notation of our theoretical model and the associated constraints.The environment features two types of license plates, two types of consumers, and a monopolist seller. Let:

- s_i denote the superstitious appeal of a license plate, such that $0 \leq s_1 < s_2$;
- p_i denote price of a license plate based on its superstitious appeal s_i;
- c_i denote the variable cost of producing a license plate with superstition level s_i
- θ_j denote the superstitious level of a consumer, such that $0 \leq \theta_1 < \theta_2$;
- $u(\theta_j, s_i)$ denote the utility function of consumer θ_j acquiring a license plate with s_i superstition level;
- $v(\theta_j, s_i, p_i)$ denote consumer valuation function, capturing utility net of price
- λ denote the market share of more superstitious θ_2 consumers, with $1 - \lambda$ representing the share of less superstitious θ_1 consumers, where $0 \leq \lambda \leq 1$;

License Plates

All license plates are identical in length and physical design, differing only in their superstitious appeal, which is determined by the presence of auspicious or inauspicious numerals. We assume license plates cannot be resold. While high-value plates are non-transferable after auction in Hong Kong and others may be transferable, the transferable aspect is beyond the scope of this research.

Superstitious appeals s_1 *and* s_2 are exogenous as producers cannot arbitrarily vary the numeral combinations of a plate, and only a limited number of superstitious combinations exist within a fixed numeral series.

Consumers

Utility and valuation function

Each consumer demands exactly one license plate. The consumer's outside option yields zero utility. Therefore, the consumer's surplus (or valuation) function is defined as:

$$v(\theta_j, s_i, p_i) = \begin{cases} u(\theta_j, s_i) - p_i \; if the consumer purchases 1 unit of good \\ 0 \quad otherwise \end{cases}$$

Type Dominance

The more superstitious θ_2 consumers derive greater utility compared to less superstitious θ_1 consumers, for a given superstitious appeal s_i of the plate. Thus, for any fixed s_i,

$$u(\theta_2, s_i) > u(\theta_1, s_i) \tag{5.1}$$

Product Dominance

All consumers agree that a license plate with higher superstitious appeal s_2 is more valuable than one with lower appeal s_1, because the definition of s_i is universally understood in the market and its value is observable.. Therefore, for any fixed θ_i:

$$u(\theta_i, s_2) > u(\theta_i, s_1) \tag{5.2}$$

Single-crossing property

To implement a screening mechanism that allows truthful self-selection among consumers (agents) based on plate valuations, the model assumes the standard Spence–Mirrlees (single-crossing) condition holds (Laffont and Martimort, 2002). Specifically, more superstitious consumers not only derive greater utility from a given s_i, but also experience a larger marginal increase in utility from plates with higher superstitious appeal ,

$$u(\theta_2, s_2) - u(\theta_2, s_1) > u(\theta_1, s_2) - u(\theta_1, s_1) \tag{5.3}$$

The utility function $u(\theta, s)$ needs to satisfy the following to hold the single-crossing property:

$$u_s(\theta, s) = \frac{\partial u(\theta, s)}{\partial s} > 0, \qquad u_\theta(\theta, s) = \frac{\partial u(\theta, s)}{\partial \theta} > 0$$

$$u_{\theta s}(\theta, s) = \frac{\partial \frac{\partial u(\theta, s)}{\partial \theta}}{\partial s} > 0$$

These ensure that utility increases with both superstition level and consumer type, and that the interaction effect is positive. Without these conditions, the relative preferences of high- and low-valuation drivers could reverse, making truthful self-selection impossible.

Producer

Typically, the license plate market operates as a government-controlled monopoly, with authorities responsible for the issuance and pricing of plates. Attempts to decentralize or foster competitive license plate markets through private entities often encounter significant logistical and administrative complexities (Asif, 2024). Within our model, the government acts as the sole distributor, able to set prices in the market.

Cost function

Given that license plates with higher superstitious appeal are more scarce than normal license plates and requires more lobbying cost in identifying and reserving them,

We assume that the production cost of each plate depends on its superstitious appeal and that the fixed cost is zero. We also assume that the consumer's utility from a plate exceeds its production cost,

$$c_i < u(\theta_j, s_i)$$

We assume that the increase in cost for producing a license plate with higher superstitious attributes is smaller than the increase in low-type consumer's utility of consuming a higher type license plate,

$$u(\theta_1, s_2) - u(\theta_1, s_1) > c_2 - c_1 \tag{5.4}$$

Example

The high-type plates (with $\boldsymbol{s_2}$) contain numerals or numeral combinations widely viewed as auspicious (e.g., AB8856 with auspicious numeral "8" and "6"), whereas low-type license plates (with $\boldsymbol{s_1}$) are more common and lack superstitious numerals (e.g., AB4513 with numeral "1," "5," "3" and inauspicious numeral "4") All license plates equate in the length and physical design.

The more superstitious θ_2 consumers could represent the Chinese buyers, or the older generations steeped in numerology. The less superstitious θ_1 consumers could represent those of other cultures that are unfamiliar with Chinese lucky numbers or younger, more rational individuals.

6 Model Analysis

6.1 Complete information

Under complete information, both monopolist and consumers know everything about the game set-up, including the type θ_j of each individual consumer, the willingness to pay (WTP) $u(\theta_j, s_i)$, and the superstitious appeal s of every plate.

One type of license plate and one type of consumer

A monopolist with perfect information can charge the full willingness to pay of each individual consumer, which is $u(\theta_j, s_i)$. The consumers receive no surplus.

$$p_1^* = u(\theta_1, s_i)$$

$$p_2^* = u(\theta_2, s_i)$$

If there is only one consumer type, θ_i, and one plate type with appeal s, the monopolist sets price equal to that type's full willingness to pay, $p = u(\theta_j, s_i)$. The producer surplus equals to the summation of the willingness to pay of every consumer in the market minus the production cost:

$$\Pi = n_i u(\theta_j, s_i) - c_i$$

S as an endogenous variable

Assume the monopolist can freely choose the level of appeal. Inequality (5.4) in the previous section states that $u(\theta_1, s_2) - u(\theta_1, s_1) > c_2 - c_1$. Even when all buyers are the less-superstitious type θ_1, the gain in their willingness to pay for a high-appeal plate s_2 exceeds the extra production cost. Hence, regardless of the market mix, the profit-maximizing firm always supplies plates with appeal s_2 and earns

$$\Pi = \sum_{i=1}^{n} u(\theta_j, s_2) - c_2$$

S as an exogenous variable

In reality, only a limited set of number combinations qualifies as "lucky," so the supply of s_2 plates may be exhausted. If that constraint binds, the monopolist must switch to the low-appeal plate s_1, yielding

$$\Pi = n \cdot [u(\theta_j, s_1) - c_1]$$

When the constraint is only partial (a finite stock of s_2 plates), the firm faces an allocation problem; the next section analyses that case with two plate types and two consumer types.

Welfare

In the full-information benchmark, the producer's profit equals the sum of each buyer's willingness to pay, limited only by the total number of plates it can supply. Because the firm prices every unit at the corresponding valuation, there is no deadweight loss: every consumer who values a plate at or above its cost receives one, and total output is efficient. A government monopolist may find this profit-maximizing strategy appealing on welfare grounds as well, since it eliminates deadweight loss and allows the revenue to be recycled through public spending or targeted transfers.

6.2 Incomplete Information and Adverse Selection

In reality, the monopolist typically does not have perfect information. Instead, it knows the population shares ($\boldsymbol{\lambda}$ for type $\boldsymbol{\theta}_2$, and $\mathbf{1} - \boldsymbol{\lambda}$ for type $\boldsymbol{\theta}_1$) and the utility functions $\boldsymbol{u}(\boldsymbol{\theta}_j, \boldsymbol{s}_i)$. This creates an adverse selection problem where the seller cannot observe individuals' type $\boldsymbol{\theta}_j$; hence, more superstitious $\boldsymbol{\theta}_2$ buyers may mimic less superstitious $\boldsymbol{\theta}_1$ buyers to pay less.

Under incomplete information, the monopolist is unable to cater to each individual's exact willingness to pay and therefore cannot fully extract all consumer surplus. Instead of pricing each plate based on individual valuation, the monopolist may adopt one of two pricing regimes to maximize profit:

1. **Uniform pricing**$\{s, p\}$: offer one plate superstitious for appeal level s_1 or s_2 at a single price
2. **Menu pricing (third-degree price discrimination):** offer two bundles (s_1, p_1) and (s_2, p_2), relying on self-selection.

A rational monopolist compares the expected profits under each regime and selects the one that yields the highest return.

6.2.1 Uniform pricing

Because (5.4) guarantees that a high-appeal plate yields more gross surplus than a low-appeal plate, the monopolist always produces s_2[3]. It then decides whether to

- sell only to high types λ_2 for (θ_2), or
- serve the whole market ($\lambda_1 + \lambda_2$ for θ_1 and θ_2) at a price affordable to both.

Let (6.1) denotes the profit for only serving the θ_2 market and (6.2) denotes the profit for serving both θ_1 and θ_2 markets[4]. Let Π^u denotes monopoly profit with uniform pricing,

$$\Pi^u = \begin{cases} \lambda \cdot (u(\theta_2, s_2) - c_2) & (6.1) \\ u(\theta_1, s_2) - c_2 & (6.2) \end{cases}$$

The monopolist chooses to only serve the high type θ_2 market if $\Pi_{6.1} \geq \Pi_{6.2}$, which holds if

$$\lambda \leq \frac{u(\theta_1, s_2) - c_2}{(u(\theta_2, s_2) - c_2)} \equiv \lambda^0$$

[3] See Appendix C for full mathematical proof that supports the monopolist's strategy in always selling s_2 plates.
[4] See Appendix D for the derivation for (6.2).

The threshold λ where a profit-maximizing monopolist would switch from serving both consumer types to only θ_2 highly superstitious consumers is denoted as λ^0. Thus, for small markets of superstitious buyers ($\lambda \leq \lambda^0$) the monopolist serves everyone at a common price; otherwise, it excludes less-superstitious types.

Governments concern beyond profit maximization, and license plates can be viewed as necessities in regions with limited public transportation. Therefore, the monopolist would not want to use uniform pricing that excludes θ_1 consumers, regardless of its potential earnings.

6.2.2 3rd-degree Price Discrimination, Menu Pricing (Adverse-Selection)

Instead of a uniform pricing strategy, the monopolist can also choose to discriminate based on consumer types, design two product packages constituting a combination of superstitious appeals of a license plate and price (s_1, p_1) and (s_2, p_2) that allow each type of consumer to self-select into the matching product bundles, maximizing the producer's surplus. The superstitious appeal (s_1, s_2) are exogenous to the monopolist.

Let Π^d denotes the monopoly's profit function with price discrimination, then the profit maximization function is:

$$\max_{p_1, p_1} \Pi^d = (1 - \lambda) \cdot (p_1 - c_1) + \lambda \cdot (p_2 - c_2) \tag{6.3}$$

, and we assume the market is fully covered.

Under effective product bundles, consumers reveal their types as they select the bundles.

Individual Rational / Participation Constraint

Since consumers' outside option is buying nothing, which yields $\{0\}$ value, to incentivize consumers to participate, their valuation of the license plate must satisfy the following.

$$u(\theta_1, s_1) - p_1 \geq 0 \tag{6.4}$$

$$u(\theta_2, s_2) - p_2 \geq 0 \tag{6.5}$$

Incentive Compatibility Constraint

Meanwhile, for effective price discrimination, the consumers must have no incentive to deviate from their matched bundle. This specifically entails that highly superstitious consumers θ_2 would be incentivized to choose the bundle with s_2, license plate with higher superstitious appeal, having no incentive to deviate or buy the low-price package. Similarly, the low type θ_1 should have no incentive to deviate from buying the product bundle with s_1. To satisfy the incentive compatibility constraint, the $\{s_1, p_1\}$ and $\{s_2, p_2\}$ must satisfy the following.

$$u(\theta_1, s_1) - p_1 \geq u(\theta_1, s_2) - p_2 \tag{6.6}$$

$$u(\theta_2, s_2) - p_2 \geq u(\theta_2, s_1) - p_1 \tag{6.7}$$

If all four constraints (6.4 to 6.7) are met, the monopolist can discriminate against the two types of consumers and charge different prices. The following section will show that only (6.4) and (6.7) constraints are binding. A rational monopolist would find the binding constraints and maximize its profit function (6.3) based on them.

Binding Constraints

Given (5.1), the highly superstitious consumers $\boldsymbol{\theta_2}$ value a license plate at any given $\boldsymbol{s}$ more than less superstitious consumers $\boldsymbol{\theta_1}$,

$$u(\theta_2, s_1) > u(\theta_1, s_1) \tag{5.1}$$

if less superstitious consumers θ_1 are willing to participate for the current bundle offering (6.4) $\{s_1, p_1\}$, the highly superstitious consumer is willing to buy $\{s_1, p_1\}$ too. Subtracting p_1 from both side,

$$u(\theta_2, s_1) - p_1 > \ u(\theta_1, s_1) - p_1 > 0$$

Since that highly superstitious consumer θ_2 is incentivized to buy the high-type bundle over the low-type bundle (6.7),

$$u(\theta_2, s_2) - p_2 \geq u(\theta_2, s_1) - p_1 \tag{6.7}$$

Then, the highly superstitious consumers θ_2 are willing to participate (6.5). This result is shown below:

$$u(\theta_2, s_2) - p_2 \geq u(\theta_2, s_1) - p_1 > \ u(\theta_1, s_1) - p_1 > 0$$

$$u(\theta_2, s_2) - p_2 \geq 0 \tag{6.5}$$

Therefore, if less superstitious consumers participate in the market (6.4) and more superstitious consumers value high-type bundle over the low-type bundle (6.7), the more superstitious consumers also participate (6.5). The participation constraint of highly superstitious consumers is not binding, but of the less superstitious consumers is[5].

Constrained maximization

Participation constraint for low-type consumers θ_1 (6.4) and the incentive compatibility constraint for high type consumers θ_2(6.7) are binding:

$$p_1 \leq u(\theta_1, s_1)$$

---

[5] See full proof of (6.6) not binding in Appendix E.

$$p_2 \le p_1 + u(\theta_2, s_2) - u(\theta_2, s_1)$$

The monopolist would choose the highest $\{p_{1,}p_2\}$ possible within the binding constraints to maximize profit. Since (6.4) is binding, to maximize profit. Maximize p_1 with respect to (6.4) constraint,

$$p_1^* = u(\theta_1, s_1) \tag{6.8}$$

Hence, rewriting (6.7) with $p_1^* = u(\theta_1, s_1)$ and maximize p_2 with respect to (6.7)[6],

$$p_2^* = u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] \tag{6.9}$$

To understand this with our license plate market, less superstitious consumers would be charged with their full WTP, but the more superstitious consumers would earn a surplus. The bracketed term is the information-rent deduction to stop θ_2 from mimicking θ_1, the firm must leave θ_2 some surplus that would be as big as if θ_2 pretend to be θ_1.

The monopolist's profit function (6.3) with optimal prices p_1^* and p_2^* is:

$$\max_{p_1, p_1} \Pi^d = (1-\lambda)\cdot(u(\theta_1, s_1) - c_1) + \lambda\cdot(u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] - c_2) \tag{6.10}$$

Price discrimination versus uniform pricing

We assume the government excludes the situation that excludes part of the market (e.g., not selling to less superstitious consumers), given that the government wants to provide transportation accessibility to everyone. Therefore, we only compare uniform pricing that serves both markets and price discrimination results.

To compare Π^u and Π^d, menu pricing dominates uniform pricing when that $\Pi^d \ge \Pi^u$

$$(1-\lambda)\cdot(u(\theta_1, s_1) - c_1) + \lambda\cdot(u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] - c_2) \ge u(\theta_1, s_2) - c_2$$

which holds if[7]

$$\lambda \ge \frac{u(\theta_1, s_2) - u(\theta_1, s_1) - c_1 - c_2}{u(\theta_2, s_2) - u(\theta_2, s_1) + c_1 - c_2} \equiv \tilde{\lambda}$$

We denote the threshold λ as $\tilde{\lambda}$. If λ is greater than $\tilde{\lambda}$, the profit for price discrimination (Π^u) is higher than profit with uniform pricing (Π^d) in the condition of serving both high-type θ_2 and low-type $\theta_1$markets. A larger share of highly superstitious buyers (higher λ) makes discrimination more profitable because the extra margin the firm can charge θ_2 consumers outweighs the information rents left to them.

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[6] See full derivation in Appendix F
[7] See full derivation in Appendix G.

6.3 Price Discrimination Outcome under Complete and Incomplete Information

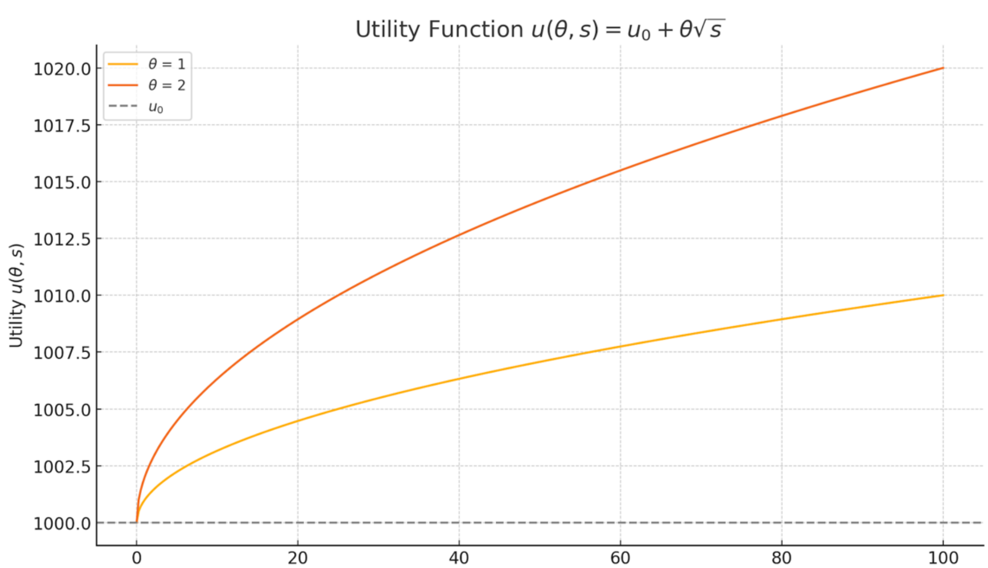
Under both complete and incomplete information, the monopolist charges the full willingness to pay of the less superstitious θ_1 consumers. However, under incomplete information, the monopolist must pay an information rent of $[(u(\theta_1, s_1) - u(\theta_2, s_1)]$ to incentivize the highly superstitious consumers consumers to select the plates with higher superstitious appeal, paying additional premium value. This information-rent is the amount of additional surplus that θ_2 consumers could obtain by pretending they are θ_1 consumers. Therefore, monopolist needs to balance revenue extraction and self-selection constraints when consumer types are not observable.

7 Combine Empirical Result and Theoretical Model

Our study uses a concrete utility function to understand superstitiousness of Hong Kong license plate consumers, assigns superstitious appeal to plates, and then applies auction prices data to find premium values that each type of consumer is willing to pay for their corresponding type of license plate. Utilizing a concave utility function, we will calibrate the parameters to find the premium value each type of consumer is willing to pay.

$$u(\theta, s) = u_0 + \theta\sqrt{s}$$

Figure 7.1 Utility Function $u(\theta, s) = u_0 + \theta\sqrt{s}$ with $u_0 = 1000$



We assume $u_0 = 1000$, represented in the graph as well, because \$1000 is the reservation price of a license plate in Hong Kong auctions and the approximate price to get a license plate through allocation instead of auction.

The utility function $u(\theta, s) = u_0 + \theta\sqrt{s}$ satisfies the single-crossing conditions (5.3) listed in Section 5, also representing a diminishing return on superstition.

$$u_s(\theta, s) = \frac{\partial u(\theta, s)}{\partial s} = \frac{1}{2}\theta s^{-\frac{1}{2}} > 0, \qquad u_\theta(\theta, s) = \frac{\partial u(\theta, s)}{\partial \theta} = \sqrt[2]{s} > 0$$

$$u_{\theta s}(\theta, s) = \frac{\partial \frac{\partial u(\theta, s)}{\partial \theta}}{\partial s} = \frac{1}{2}s^{-\frac{1}{2}} > 0$$

Replacing $u(\theta, s)$ in generic equilibrium prices (6.8) and (6.9) with the concave utility function, the equilibrium prices p_1^* and p_2^* are:

$$p_1^* = u_0 + \theta_1\sqrt{s_1} \tag{7.1}$$

$$p_2^* = \theta_2\sqrt{s_2} - (\theta_1\sqrt{s_1} - \theta_2\sqrt{s_1}) \tag{7.2}$$

Combining with the data from Hong Kong license plate we can estimate $\mathbb{E}\,[\theta_1\sqrt{s_1}]$and $\mathbb{E}\,[\,\theta_2(\sqrt{s_2} - \sqrt{s_1})]$ to understand how much premium value each type of consumer pays. We index license plates, assign them $s_1 = 1$ or $s_2 = 1$ dummy variables. Given the empirical regression analysis, we assign the plates that include numerals “8, 68, or 28” $s_2 = 1$, otherwise with $s_1 = 1$ attribute.

$$p_1^* = 1000 + \theta_1\sqrt{s_1} + \varepsilon_i$$

$$p_2^* = 1000 + \theta_2\sqrt{s_2} + (\theta_1\sqrt{s_1} - \theta_2\sqrt{s_1}) + \varepsilon_i$$

We assume the consumer’s valuation has a variation of ε_i that is normally distribution. Specifically, this ε_i potentially includes idiosyncratic buyer preferences and valuations, as well as unobserved factors such as individual aesthetic preferences, bidding competition intensity, or individual-level wealth variation.

Then, we compute the average price of p_1, ε_i drops given the normal distribution, then get estimated $\theta_1\sqrt{s_1}$,

$$\overline{p_1} = \mathbb{E}\,[1000 + \theta_1\sqrt{s_1}] \text{ conditional on } = s_1$$

Given that $\overline{p_1} = 7286$ rounding to the last digit,

$$\mathbb{E}\left[\theta_1\sqrt{s_1}\right] = 6286$$

Hence,

$$\overline{p_2} = 7286 + \mathbb{E}\left[\theta_2(\sqrt{s_2} - \sqrt{s_1})\right]$$

Given that $\overline{p_2} = 12623$,

$$\mathbb{E}\left[\theta_2(\sqrt{s_2} - \sqrt{s_1})\right] = 5337$$

$\theta_1\sqrt{s_1}$ represents the premium value that a less superstitious consumer pays for a license plate with s_1 appeal in comparison to buying a plate with no superstitious appeal at all. $\theta_2(\sqrt{s_2} - \sqrt{s_1})$ represents the premium value that a highly superstitious consumer pays for a license plate with s_1 appeal over s_2 appeal. This valuation on change in superstitious value Δs is also the distortion of how much more θ_2 consumers pay for a license plate than θ_1 consumers.

The results show that superstition carries substantial monetary value in this market—amounting to a premium of $6,286 for less superstitious buyers and an additional $5,337 for more superstitious buyers. These figures reinforce that consumers are willing to pay significant amounts to secure numerologically auspicious license plates. Furthermore, since the high-type additional premium is smaller than the low-type premium ($5,337 < $6,286), we observe diminishing marginal valuation for lucky numbers, which aligns with our assumption of a concave utility function. Also, by explicitly quantifying superstition-driven valuation distortions, the premium values provide evidence for market segmentation based on superstitious beliefs.

If the current auction system becomes unsustainable—due to logistical, political, or operational constraints—the government could implement a two-tier pricing strategy. By bundling plates into high- and low-superstition categories and pricing them accordingly, the government can continue to extract consumer surplus and maximize revenue without holding individual auctions for each plate. Although this approach would only capture the willingness to pay of highly superstitious buyers at a discount, it could still be beneficial by significantly reducing the logistical costs of organizing auctions.

Governments in regions like Mainland China, where a license plate auction system may not yet be mature but where superstition remains culturally significant, could adopt a version of this model. If consumer types can be estimated from alternative data sources (e.g., mobile number purchases, past bidding patterns), authorities could introduce differentiated pricing or allocation systems that optimize both revenue and consumer welfare.

8 Conclusion

This study investigates the valuation dynamics within Hong Kong's license plate market, illustrating the potent influence of numerological superstition on consumer behavior. By employing both empirical analyses of auction data and theoretical price discrimination models, the study uncovers significant pricing patterns likely driven by cultural numerological beliefs.

Empirical findings from this research underscore that numerological superstition notably influences consumer willingness-to-pay. Numbers traditionally deemed auspicious—particularly “8,” “6,” “2,” and “9”—significantly elevate license plate valuations. Replacing a neutral number such as “0” with “8” increases a plate’s valuation by 64.8 percent.

Furthermore, combinations of numbers such as "28," "68," and “88” command substantial premiums, revealing that lexical combinations add distinct economic value beyond the individual values of their composite numbers. A plate containing the numeral “28” is priced 42.9 percent higher than other plates with similar letter and numeral patterns but without “28.”

The theoretical exploration of uniform and third-degree price discrimination frameworks elucidates how governments, acting as monopolists in this market, could strategically structure pricing to maximize welfare and extract consumer surplus. Specifically, by segmenting consumers based on superstitious valuations, governments can implement differentiated pricing strategies that effectively capitalize on preferences without compromising on consumer welfare.

The paper finds that numerological superstition in the Hong Kong license plate market leads to a willingness to pay a premium of $6,286 for less superstitious buyers and an additional $5,337 for more superstitious buyers. This provides insights into concrete price discrimination strategies the government could adopt and supports the assumption of diminishing marginal utility from superstition at the individual level.

We acknowledge limitations, notably the exclusion of personalized plates and potential selection biases inherent in auction-based datasets. Future research can expand upon this work by incorporating personalized plates, extending analyses to other numerological influenced commodities such as phone numbers or lottery tickets. The methods described in this paper can also be applied to other license plate markets where, like Hong Kong, cars and their associated registration marks are more of a luxury good rather than a necessity.

Ultimately, this research contributes to existing literature by quantifying superstition-driven valuation distortions and offering practical insights into optimal pricing strategies. Policymakers and businesses alike can leverage these findings to improve market efficiency and consumer satisfaction, highlighting broader implications for markets where cultural or symbolic values profoundly influence pricing structures.

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Appendix

Appendix A Sample physical feature of a Hong Kong standardized license plate.

Note. All Hong Kong license plate should be displayed as black letters and numerals upon a white background on the front of a vehicle, and black letters and numerals upon a yellow background on the back of a vehicle

Appendix B Full Table for Numeral Count Regression Results, Controlling Numeral and Letter Pattern

Numeral Count Regression Results, Controlling Numeral and Letter Pattern

	Dependent variable:			
	log(Price_clean)			
	(1)	(2)	(3)	(4)
num_1	0.202***	0.197***	0.183**	0.229***
	(0.058)	(0.058)	(0.080)	(0.061)
num_2	0.310***	0.269***	0.246***	0.190***
	(0.063)	(0.064)	(0.092)	(0.071)
num_3	0.338***	0.332***	0.260***	0.183***
	(0.063)	(0.063)	(0.082)	(0.064)
num_4	-0.109	-0.121	-0.017	-0.045
	(0.078)	(0.078)	(0.115)	(0.088)
num_5	-0.103	-0.115	-0.235**	-0.126
	(0.077)	(0.077)	(0.101)	(0.078)
num_6	0.321***	0.298***	0.232***	0.184***
	(0.060)	(0.062)	(0.084)	(0.065)
num_7	-0.018	-0.016	-0.065	-0.074
	(0.070)	(0.070)	(0.093)	(0.072)
num_8	0.688***	0.525***	0.480***	0.500***
	(0.055)	(0.069)	(0.092)	(0.071)
num_9	0.332***	0.330***	0.253***	0.282***
	(0.059)	(0.059)	(0.078)	(0.060)
digit_count	-1.023***	-1.023***	-1.276***	-1.371***
	(0.059)	(0.059)	(0.098)	(0.076)
has_28		0.428***	0.441**	0.357***
		(0.139)	(0.176)	(0.136)
has_68		0.218*	0.480***	0.346***
		(0.113)	(0.137)	(0.106)
has_88		0.408***	0.259	0.318**
		(0.134)	(0.169)	(0.130)
aaaa			2.823***	2.588***
			(0.495)	(0.381)
aaa			0.805***	0.893***
			(0.105)	(0.081)
aa			0.158*	0.170**
			(0.090)	(0.069)
abab			0.868***	1.243***

			(0.310)	(0.239)
aabb			0.938***	0.970***
			(0.275)	(0.211)
abac			0.134	0.162
			(0.145)	(0.112)
baca			-0.223	-0.061
			(0.194)	(0.149)
symmetric			0.513*	0.569***
			(0.276)	(0.213)
abc			0.675*	0.603*
			(0.399)	(0.307)
ab			-0.224**	-0.023
			(0.095)	(0.074)
cba			0.017	0.160
			(0.310)	(0.238)
ba			0.165	-0.0002
			(0.108)	(0.084)
hundreds			-0.056	0.102
			(0.306)	(0.236)
thousands			1.019*	1.226***
			(0.594)	(0.457)
letter_aa				0.835***
				(0.068)
no_letters				3.289***
				(0.281)
Date Fixed Effects:	X	X	X	X
Digit count controlled:	X	X	X	X
Numeral combos controlled:		X	X	X
Numeral patterns controlled:			X	X
Letter patterns controlled:				X
Observations	1,067	1,067	548	548
R^2	0.411	0.421	0.607	0.769
Adjusted R^2	0.402	0.410	0.582	0.753
Residual Std. Error	0.812 (df = 1050)	0.806 (df = 1047)	0.771 (df = 514)	0.593 (df = 512)
Note:	*p<0.1; **p<0.05; ***p<0.01			
	Two-tailed p-value. Standard errors in parentheses.			

Appendix C Complete Information: Proof of the monopolist's preference of producing plates with higher superstitious appeal s_2

Given (5.4),

$$u(\theta_1, s_2) - u(\theta_1, s_1) > c_2 - c_1 \quad (5.4)$$

Reorganizes,

$$u(\theta_1, s_2) - c_2 > u(\theta_1, s_1) - c_1$$

We can see there is more surplus that the monopolist can extract by producing and selling s_2 plates over s_1 plates. Recall that the monopolist also charges full $u(\theta_j, s_i)$ in complete information.

Appendix D Incomplete Information Uniform Pricing: Driving the monopolist profit for uniform pricing serving both θ_1 and θ_2 markets

Since the monopolist want to sell to both types of consumers, it maximizes its price by less superstitious consumers' willingness to pay $u(\theta_1, s_2)$ for both types of consumers

$$\Pi^u = (u(\theta_1, s_2) - c_2) \cdot (1 - \lambda) + (u(\theta_1, s_2) - c_2) \cdot (\lambda)$$

Reorganizes,

$$\Pi^u = (u(\theta_1, s_2) - c_2)$$

Appendix E Incomplete Information: Proof of the non-binding nature of (6.6) by contradiction

If (6.6) is not true,

$$u(\theta_1, s_1) - p_1 < u(\theta_1, s_2) - p_2$$

$$p_1 > p_2 - [u(\theta_1, s_2) - u(\theta_1, s_1)]$$

(6.7) could be rewritten as

$$p_2 \geq p_1 + u(\theta_2, s_1) - u(\theta_2, s_2)$$

Replace p_1,

$$p_2 \geq p_2 - [u(\theta_1, s_2) - u(\theta_1, s_1)] + u(\theta_2, s_1) - u(\theta_2, s_2)$$

Reorganize,

$$[u(\theta_1, s_2) - u(\theta_1, s_1)] \geq u(\theta_2, s_1) - u(\theta_2, s_2)$$

This contradicts with the single-crossing property (5.3),

$$u(\theta_2, s_2) - u(\theta_2, s_1) > u(\theta_1, s_2) - u(\theta_1, s_1) \tag{5.3}$$

If (6.6) is not true, then (6.7) is not true. If (6.7) is true, then (6.6) must be true. (6.5) participation constraint for the high type is not binding given the game assumption of the single-crossing property.

Appendix F Incomplete Information Price Discrimination: Algebraic derivation of (6.9) from (6.7)

Recall the participation constraint of highly superstitious buyers (6.7)

$$u(\theta_2, s_2) - p_2 \geq u(\theta_2, s_1) - p_1 \tag{6.7}$$

Reorganizes,

$$p_2 \leq p_1 + u(\theta_2, s_2) - u(\theta_2, s_1)$$

Recall (6.8)

$$p_1^* = u(\theta_1, s_1) \tag{6.8}$$

Replace p_1 with p_1^*,

$$p_2 \leq u(\theta_1, s_1) + u(\theta_2, s_2) - u(\theta_2, s_1)$$

Maximizes p_2 given the binding constraint (6.7),

$$p_2 = u(\theta_1, s_1) + u(\theta_2, s_2) - u(\theta_2, s_1)$$

Reorganizes,

$$p_2^* = u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] \tag{6.9}$$

Appendix G Incomplete Information: Derivation of $\tilde{\lambda}$

Compare Π^u and Π^d that $\Pi^d \geq \Pi^u$ if

$$(1-\lambda)\cdot(u(\theta_1, s_1) - c_1) + \lambda\cdot(u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] - c_2) \geq u(\theta_1, s_2) - c_2$$

Reorganize,

$$(1-\lambda)\cdot(u(\theta_1, s_1) - c_1) + \lambda\cdot(u(\theta_2, s_2) + [(u(\theta_1, s_1) - u(\theta_2, s_1)] - c_2) \geq u(\theta_1, s_2) - c_2$$

$$(u(\theta_1, s_1) - c_1) - (\lambda)\cdot(u(\theta_1, s_1) - c_1) + \lambda\cdot u(\theta_2, s_2) + \lambda[(u(\theta_1, s_1) - u(\theta_2, s_1)] - \lambda c_2$$
$$\geq u(\theta_1, s_2) - c_2$$

$$(u(\theta_1, s_1) - c_1) + (\lambda)\cdot(c_1) + \lambda\cdot u(\theta_2, s_2) - \lambda\cdot u(\theta_2, s_1) - \lambda c_2 \geq u(\theta_1, s_2) - c_2$$

$$(\lambda)\cdot(u(\theta_2, s_2) - u(\theta_2, s_1) + c_1 - c_2) \geq u(\theta_1, s_2) - u(\theta_1, s_1) - c_1 - c_2$$

Conclude,

$$\lambda \geq \frac{u(\theta_1, s_2) - u(\theta_1, s_1) - c_1 - c_2}{u(\theta_2, s_2) - u(\theta_2, s_1) + c_1 - c_2} \equiv \tilde{\lambda}$$