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JEL Classification: D2, L1, L82, Z11

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May 1, 2021

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1 Introduction

Movie theaters with very different characteristics often compete in the same local market. This is in part due to innovations in movie exhibition technologies, such as the introduction of the multiplex in the early 70's and more recently the growth in Imax screens, as well as changes in movie supply.[1] Although not all movie theaters are made the same, little is known about the impact of theater characteristics on theater success. With the exception of studies of spatial differentiation (Davis, 2006a), the large literature studying the movie industry has paid surprisingly little attention to the role of outlet characteristics in the movie exhibition sector (McKenzie, 2012). It is possible, after all, that theater characteristics have no significant impact on theater success?

This paper focuses on three theater characteristics, which we refer to as *theater design*: the number of auditoria, the seating capacity (the average number of seats per auditorium), and whether a theater has an Imax auditorium. The first two choices, which we label *theater scale*, are common to all theaters. Imax screening technology is a growing segment of the movie exhibition market that sheds light on the existence of spillovers in offering a premium viewing technology. We study the impact of these theater characteristics on the theater revenues earned from regular auditoria, that is, excluding the revenues from the Imax auditorium.[2]

According to the theater design neutrality hypothesis, the exhibition technology is scale additive and there are no spillovers: (a) each additional seat brings the same incremental revenue, (b) the same holds for auditorium, and (c) there are no spillover effect of adding an Imax auditorium on the revenue of non-Imax auditoria. We test whether theater design neutrality holds using a large dataset, covering years 2012 to 2016, and the majority of theaters in the fast growing Chinese market, which has received relatively little attention in the literature (Gil, Ho, Xu, and Zhou, 2018, Ho, Liang, Weinberg, and Yan, 2018). We select 400 local markets with large theaters, and at least one Imax theater, and compare theater revenues within each local market, using a quarterly time series, and controlling for local demand, product characteristics, and competition.

To understand the impact of theater scale on revenue, we estimate a variety of functional forms including Cobb-Douglas, translog, semi-parametric, and piecewise Cobb-Douglas. This agnostic approach lets the data reveal the relationship between theater design and revenues. All specifications reject theater design neutrality. We find instead:

[1] According to Hanson (2019), the fist multiscreen theater was opened in 1969 in Omaha, Nebraska. Other innovations include changes in sound and image quality (e.g. dolby, THX), digital cinematography...

[2] Studying the impact of scale on revenue has been done in other industries (e.g. Wheelock and Wilson (2018)).

(a) increasing returns to adding auditorium in theater complex that have up to 9 auditoria, beyond which constant returns hold, (b) close to constant returns to adding seats up to about 120 seats beyond which there are strong decreasing returns, (c) complementarity between auditorium and seat in small theater complexes, and (d) a large revenue premium from adding an Imax auditorium. We discuss plausible mechanisms to organize the findings, and conclude that revenues are maximized for theaters with 9 or more auditoria and a seating capacities around 120 seats.

We further use a unique property of movie theater revenues to decompose these deviations from theater design neutrality: the revenue per seat is the product of screening intensity (number showings per auditorium), seat utilization rate (fraction of available tickets that are sold), and ticket price. The increasing return in auditorium count is largely explained by an increase in seat utilization rate, and to a lesser extent by a higher screening intensity. The positive return to seating capacity at low scale is largely explained by a higher screening intensity, while the decreasing returns at high scale is explained by lower seat utilization rates. Consistent with the literature (Orbach and Einav, 2007), ticket price plays a small role in explaining the deviations from theater design neutrality.

Imax and classic theaters are very similar with the main difference that the former have an Imax auditorium in addition to regular auditoria. Adding an Imax auditorium, to an otherwise observationally identical theater, increases the revenue from its regular auditoria by a staggering 45%, which we decompose into three components, as we did for theater scale. About two-third of the Imax premium is explained by a higher seat utilization rate, with the rest being explained by a price premium, leaving little explanatory role for screening intensity. Moreover, the Imax premium is higher when the relative supply of Imax movies is large. This suggests that positive spillovers, from the Imax auditorium toward regular ones, are converted into higher capacity utilization rates and a price premium.

We conclude by testing a set of constraints that must hold under the assumption that theaters scale maximizes profits. Only theaters with 9 or more auditoria, and with an intermediate seating capacity, do not violate these inequalities. Although the majority of theaters in our sample have too few auditoria and too many seats per auditorium, we find that the theaters built between 2012 and 2016, which corresponds to the sample period used to estimate the revenue function, have on average more auditoria and fewer seats.

Section 2 situates this work within the movie literature and reviews past studies that have discussed theater characteristics. Section 3 presents the methodology adopted to estimate the theater revenue function, putting great attention to the issue of unobserved heterogeneity and functional form assumptions. Section 4 reports the main results, while the conclusion covers limitations of our work, and points toward promising research avenues to investigate the robustness of the analysis, and to explore the economic mechanisms behind the deviations from theater design neutrality.

2 Literature review, background and data

2.1 Literature review

Although there is large literature on the economics of movies, relatively few studies have looked at the economics of exhibitors. In fact, McKenzie (2012)'s literature review dedicates only 2 pages (section 3.4) to movie exhibitors and the same holds for the more recent review by Kumb, Kunz, and Siegert (2017). One exhibitor topic that has received some attention is the study of local competition, measuring business stealing, cannibalization, and agglomeration effects (Chisholm and Norman, 2012, Davis, 2006b).[3] We follow Davis (2006b) in that we attempt to explain theater revenue, but in contrast with his approach, which controls only for total local auditorium supply, without accounting for within-theater (across auditoria) spillovers, we focus on the impact of theater design, holding local competition constant. The distinction being that theater revenues in a market that has, for example, 4 theaters and a total of 20 auditoria, could depend on whether all theaters has 5 auditoria, or half of the theaters have 3 auditoria and the other half 7. This distinction is one of the focus of our study.

Theater characteristics other than location have been considered in the literature, with the caveat that such characteristics do not change over time (see Appendix 2.1). Several studies have used cross-section theater variation in auditoria count and a few studies have also used information about seat count (Rao and Hartmann, 2015). Additional dimensions of theater differentiation include sound systems (e.g. digital), auditorium quality (e.g. THX), seating design (e.g. stadium), and consumer service (Arteaga, Coronado, and Flores, 2021, Chisholm, McMillan, and Norman, 2010, Davis, 2006a). Our dataset include similar measures of theater differentiation in addition to the presence of an Imax auditorium within a theater.

Two studies have estimated consumers' demand for theater characteristics using a structural approach. Davis (2006b, Table 5, p.973) has found a modest effect of auditorium count on theater demand: an additional auditorium has about the same effect on

[3]The literature has also studied uniform pricing, revenue sharing contracts, and programming and scheduling decisions (playing time, release date, movie run) and whether these decisions depend on vertical integration (Corts, 2001, Filson, Switzer, and Besocke, 2005, Gil, 2009, Moul, 2008).

consumer utility as THX or sound quality. In contrast, we find strong increasing returns in auditorium count up to 9 auditoria, suggesting that a demand approach fails to capture important spillovers that are internalized at the theater level. Using a small sample of 34 theaters, Rao and Hartmann (2015, Figure 8, p. 131) find that consumers do not have definite preferences toward having more shows on smaller screens (i.e. more but smaller auditoria). Instead, an approach comparing theater revenues within local markets using thousands of observations, such as ours, reveals a more complex (scale dependent) trade-off between auditorium size and count, and points to the conclusion that most theaters have too few auditoria and too many seats. Again, a consumer demand approach may not properly account for demand externalities. Larger theaters earn more because movie fans like having more choice, and also because theater managers can have better optimize movie scheduling, and this is consistent with the evidence from scheduling studies discussed next.

The scheduling literature points toward interesting supply side explanations for the positive effect of auditorium count on theater revenues.[4] Both Fu (2009) and Gil (2009) show that theaters with more auditoria run movies over longer periods, and the former also finds no effecd of seat per auditorium on movie run. Chisholm, McMillan, and Norman (2010) show that theaters differentiation influences programming choices. This suggests that theater characteristics, and in particular auditorium count, influence scheduling decision and point toward a mechanisms through which theater design influences movie revenues. Our results show that the mechanism operates through higher seat utilization rate and to a lesser extend through higher screening intensity. The corollary is that one should control for theater characteristics in explaining a movie's success, and in particular theater scale.

Finally, the art literature has long recognized that venue size is a source of economies of scale in art performance, largely due to significant fixed costs with event productions (McKenzie, 2012, Taalas, 1997). Surprisingly, we find decreasing returns in seating capacity, at least beyond a certain seat count, and that having more auditoria at a given location increases screening intensity and seat utilization rate, suggesting that the source of increasing returns is different in movie exhibition than in art performance.

[4] Another literature shows that movie success depends on the strategic release of movie titles within a season (Einav, 2007), movie availability (Leung, Qi, and Yuan, 2019) and advertising (Moul, 2008), among other determinants...

2.2 The Chinese movie theater market

The Chinese market for movie exhibition is fast growing and has become the second largest market in the world in box office revenues. Between 2006 and 2016, the number of movie theaters has increased about eight-fold to 8,400, the number of auditoria fourteen-fold to 41,000 screens, and box office revenue eighteen-fold to 49 billion CNY.

This study distinguishes two types of movie theaters: classic and Imax. Since 1968, the Imax company has innovated with unique motion-picture immersive theater experiences, and continues to offer unique sound and visual systems on dedicated large-format screens. Imax works with producers, to support the creation of Imax movies and the conversion of regular movies into the Imax standard, and with exhibitors, to build Imax compatible auditoria. The number of Imax theaters has been growing steadily to about 1,400 auditoria worldwide, with about one third of these located in China, where the Imax format is popular because it caters to the "preference for high-tech viewing experience (...) that emphasizes visual impact".[5]

Vertical integration between movie exhibitors and distributors is common in China (Gil, Ho, Xu, and Zhou, 2018). About one third of the chains in our sample are integrated into distribution and some are even integrated into production (see Appendix 2.6). Each exhibitor negotiates movie licenses and manages ticket price, movie scheduling and screening times. Concentration is fairly low in classic theater, with the top ten theater chains controlling about 67% of national box office revenue in 2016, the top five 44%, and the largest player 13%.

While the Imax movie format accounted for only one percent of all Chinese auditoria in 2016, it commanded about four percent of total box office revenues. Imax theaters are typically located in large cities with the largest 10 Chinese cities accounting for more than one third of all Imax theaters. The market for Imax theater is fairly concentrated. Wanda is the largest player with 51% of all Imax theaters, followed by Shanghai United with 10.5%, and the rest of the market being distributed among smaller chains.

The decision to open a new theater is largely irreversible, with no theater design changes over time, and few exits (see Appendix 2.1). An entrant has to commit on a location and an overall theater design which comprises choosing a number of auditoria, possibly including an Imax auditorium, and a seating capacity for each auditorium.

[5]Li Ruigang, https://hzdaily.hangzhou.com.cn/hzrb/html

2.3 Data

The main dataset contains information about movie theaters operating in China mainland collected by Entgroup, the leading trade publication for the media and entertainment industry in China. The data is fairly exhaustive, covering approximately 85 to 95% of the theaters that are reported in the National Bureau of Statistics of China and 90% of nationwide industry revenues.

The data includes 20 quarters starting in 2012 and ending in 2016 with a total of 90K theater-quarter observations, although as explained below, our analysis uses only 24K of these. For each theater, the database reports information about its opening date, location, and the theater chain it belongs to. We converted the location information to the theater's latitude and longitude using the Baidu map. All theaters in the sample have regular auditoria and some have both regular auditoria and one Imax auditorium. No theater has two or more Imax auditoria. We call a theater with an Imax auditorium an *Imax theater* and a theater without an Imax auditorium is a *classic theater*. Thus, a classic theater has only regular auditorium while an Imax theater has one Imax auditorium and at least one regular auditorium.

For each theater, we observe the number of classic auditorium, the average number of seats per classic auditorium, and the number of seats of the Imax auditorium if there is one. We do not know if auditorium capacity varies across regular auditorium within a theater. This is not a feature of theater design that can be explored in this study. The dataset also contains information at the theater-quarter level about box office broken down by regular and Imax auditoria, number of screenings, number of tickets available, number of tickets sold, and average ticket price. From this information, a theater's revenue can be computed as the product of five components:[6]

$$R = a * s * i * u * p \tag{1}$$

where a is the number of regular auditoria, s is the average number of seats across all regular auditoria, i is the screening intensity (a theater's quarterly average screenings per auditorium), u is the seat—or capacity—utilization rate (total number of tickets sold divided total number of tickets available), and p is the average ticket price. The products $a{*}i$ and $a{*}s{*}i$ are respectively the number of screenings, or products, offered in a quarter, and the number of tickets available in a quarter. The number of products offered depends on the time-invariant auditorium count, a, and the time-varying screening decision, i, that can change from day to day, in response to movie availability and local competition.

[6] We have $R = a * s * i * \frac{Tickets\ Sold}{a{*}s{*}i} * \frac{R}{Tickets\ Sold}$ with $u = \frac{Tickets\ Sold}{a{*}s{*}i}$ and $p = \frac{R}{Tickets\ Sold}$.

Many of the theater-quarter observations cover theaters that are not located near an Imax theater. Since the purpose of this work is to compare classic and Imax theaters that compete in similar local market conditions, we restrict the sample to all Imax theaters and to regular theater-quarter observations such that the theater is located within 3 miles of an operating Imax theater on the quarter the observation is recorded. Doing so reduces the sample to 24K observations, that cover about 400 and 2280 distinct Imax and classic theaters respectively, located in 143 cities. In the robustness section, we show that the results do not change when we define local markets using one and five miles radius instead (in which case the theater-quarter observation count changes to 10 and 31 thousand respectively). There are on average 7.8 classic and .7 Imax theaters located within 3 miles of an Imax theater.

2.4 Descriptive statistics

Table 1 presents descriptive statistics. The top panel reports all 24K theater-quarter observations. The average theater has about 7 auditoria and 1063 seats, but the range of theaters scale spans 1 to 16 auditoria and 15 to 3020 for seats. The next panel reports the same statistics for classic theaters only. Classic theaters are a little smaller with 6.5 auditoria and 952 seats. The next panel does the same for the regular auditorium of Imax theaters. An Imax theater has 8.3 regular auditoria (and one Imax auditorium) with a total capacity of 1236 seats. In addition, Imax theaters have a higher screening intensity on regular auditoria (Imax theaters feature each quarter 537 movies per auditorium versus 476 for classic theaters), achieve a higher seat utilization rate (23 versus 16%) and charge more for the tickets (37 versus 30 CNY).

Turning to revenues, classic theaters earn on average 2.5M CNY per quarter. Imax revenues are the sum of regular auditorium revenues (5.7M CNY), which is the focus of this paper, and Imax auditorium revenues (.97M CNY), which are omitted in the analysis. From here onward, the terminology *Imax theater revenue* includes only the revenues from regular auditoria, and the same holds when we refer to auditorium and seat counts. Excluding the Imax auditorium revenues, an Imax theater earns about 2.3 times more than a classic theater.

3 Empirical framework

3.1 Theater design and decompositions

A theater is an Imax theater if $I = 1$ and a classic theater if $I = 0$. Let $R(a, s, I)$ denote the revenue, from regular auditoria only, of a theater of type I, with a auditoria and s seats per auditorium. We define *theater design* as the triplet (a, s, I) and *theater scale* as the pair (a, s). We propose to investigate whether theater design influences revenues through increasing, or possibly decreasing, returns in auditorium count and auditorium seating capacity, and revenue spillover from having an Imax auditorium. To do so, we compute the revenue elasticities to auditorium and seat, $\eta_a^R = \frac{\partial ln(R)}{\partial ln(a)}$ and $\eta_s^R = \frac{\partial ln(R)}{\partial ln(s)}$, and to adding an Imax auditorium $\eta_I^R = lnR(a, s, 1) - lnR(a, s, 0)$. We call η_I^R the Imax revenue premium because it excludes Imax revenues and holds constant (a, s). Our first empirical goal is to evaluate the revenue elasticities $(\eta_a^R, \eta_s^R, \eta_I^R)$ and to investigate whether (η_a^R, η_s^R) depend on theater scale.

In the context of movie theaters, an increase in scale could happen by adding an auditorium holding constant auditorium seating capacity, or by increasing auditorium seating capacity, holding constant auditorium count. The terminology 'constant return to scale' is misleading because a doubling of both a and s multiplies seating capacity by 4. Thus, we say that there is no scale effect if $\eta_a^R = \eta_s^R = 1$, increasing return in auditorium if $\eta_a^R > 1$, decreasing returns if $\eta_a^R \in [0, 1]$, and negative returns if $\eta_a^R < 0$ (the same holds for seat). We can now state our main hypotheses:

Hypothesis 1. *Theater design neutrality: (1a) There are no scale effects in theater exhibition if $\eta_a^R = \eta_s^R = 1$. (1b) There are no Imax spillover if $\eta_I^R = 0$.*

The next benchmark allows for constant scale effects, $R(a, s) = \eta_a^R ln(a) + \eta_s^R ln(s)$, and corresponds to the Cobb-Douglas case.

Hypothesis 2. *There are constant scale effects in: (a) auditorium count if η_a^R is a constant different than one, and (b) seat count if η_s^R is a constant different than one.*

In the event we reject both hypothesis 1 and 2, we conclude that there are non-constant scale effects in auditorium and/or seat count, that is, η_a^R (η_s^R) varies with a (s). Finally, there are scale interactions if auditorium and seat counts are complement or substitute in the revenue function.

Hypothesis 3. *There are no scale interactions if η_a^R is independent of s and η_s^R is independent of a.*

The second empirical goal is to identify the sources of these returns and of the Imax premium. Using equation 1 and the definition of η_x^R for $x = a, s$, we obtain the decomposition

$$\eta_x^R - 1 = \eta_x^i + \eta_x^u + \eta_x^p \quad for \quad x = a, s \tag{2}$$

where $(\eta_x^i, \eta_x^u, \eta_x^p)$ are the elasticities for variables (i, u, p) defined similarly as η_x^R. Elasticity η_a^i, for example, captures the impact of auditorium count on the number of screenings. If we find, for example, scale effects for auditorium count, $\eta_a^R \neq 1$, the decomposition attributes this deviation from theater design neutrality, $\eta_x^R - 1$, to three possible sources: screening intensity, seat utilization rate and ticket price. The same decomposition applies to the Imax revenue premium,

$$\eta_I^R = \eta_I^i + \eta_I^u + \eta_I^p, \tag{3}$$

where η_I^i, for example, is the Imax premium associated with screening efficiency.

3.2 Empirical models

The empirical analysis leverages the panel nature of the data to estimate the elasticities η_x^y for $y = R, i, u, p$ and $x = a, s, I$. Let $R_{j,t}$ denote the revenue of theater j in quarter t. We estimate econometric specifications that are variations of the following family

$$ln(R_{j,t}) = \beta_0 + F(a_j, s_j) + \alpha_I I_j + \sum_{x \in X} \beta_{R,x} x_{j,t} + \epsilon_{j,t} \tag{4}$$

where (a_j, s_j) are time invariant variables that measure theater auditorium and seat count, I_j is a dummy that is equal to one if theater j is an Imax theater, and $x_{j,t}$ is the set of control variables (fixed effects and theater characteristics) described in the next section. The parameter α_I is an estimate of η_I^R.

We consider a variety of functional forms for the function $F(a, s)$. Under Hypothesis 1 of theater design neutrality, revenue displays no scale effect in exhibition and no Imax auditorium spillover. We have $F(a, s) = ln(a) + ln(s)$ and $\alpha_I = 0$. Under Hypothesis 2, the function $F()$ belongs to the Cobb-Douglas family. To test Hypothesis 2 and 3, we estimate a translog function (Christensen, Jorgenson, and Lau, 1973), as well as the non-linear function $F(a_{j,t}, s_{j,t}) = \sum_{k>1} \beta_{a,k} I_j^k + \tilde{F}(ln(s_j))$, where I_j^k is a theater dummy that is equal to one if theater j has k auditorium, and $\tilde{F}()$ is estimated using Robinson (1988) double residual semiparametric regression estimator. We further explore the existence of interaction effects using a piece-wise Cobb-Douglas specification.[7]

To evaluate decompositions 2 and 3, we further estimate equation 4 using variables (i, u, p) as LHS variables. We obtain estimates of $(\eta_I^i, \eta_I^u, \eta_I^p)$ and $(\eta_x^i, \eta_x^u, \eta_x^p)$ for $x = a, s$. These elasticities are used in decompositions 2 and 3.

3.3 Control variables and (un)observed theater characteristics

All specifications include 4 sets of fixed effects: (1) Market fixed effects control for differences in local competition and local demand. (2) Time fixed effects control for changes in demand and competition over time. (3) Chain fixed effects control for chain specific attributes that are common to all theaters in a chain, and this includes, chain brand, movie catalogue, and vertical integration status into distribution.[8] (4) Theater age fixed effects control for unobserved product attributes that may be correlated with the year a theater was opened, such as differences in the regulatory environment, screening technology, design and style trends that prevailed at the time the theater was built.

In addition, the dataset contains four theater characteristics: (1) The majority of theaters (97%) have *3D* screens which are designed to play 3D movies with the use of vision glasses. (2) 21% of the theaters sell *VIP* tickets which offer premium customer services.[9] (3) 11% of the theaters offer *COUPLE* seats that allow two people to sit next to one another with more privacy. (4) Although the majority of theaters in the dataset play exclusively movies, a small fraction of larger auditoria are used for other purposes as well, such as conferences and business activities (Weinberg, 2018). The dummy *SPECIALTY* takes value one if the theaters' main business is movie exhibition (see Appendix 1.1).

It could still be that, even after controlling for these variables, one or more of the theater design variables (s, c, I), are correlated with unobserved theater characteristics. For example, a theater that has more auditoria may also offer unique amenities such as larger seats, better food, more convenient parking, on so on... Keeping in mind that unobserved theater characteristic is a possibility that cannot be entirely ruled out, as is often the case, a few points specific to our application are important to highlight: (1) The analysis covers the main variables used in the literature. In addition, any hope to make

[7]This is a compromise we have to make to estimate interaction effects. While it takes an additional $A + S - 2$ auditorium and seat counts dummy variables to estimate non-linearities in returns, allowing a general functional form with interaction effects requires an additional $A * S - 1$ coefficients which is numerically impractical.

[8]Chinese theaters must source movies from a single chain, independently of ownership status. A theater that is not owned by the chain it sources its movies from, selects what movie to screen and its daily schedule independently.

[9]VIP seats typically offer (a) access to private and comfortable lounges; (b) comfortable seats; and (c) complementary snacks and drinks.

progress with 'better data' is limited because theater design does not change over time (see Appendix 2.1). (2) At the minimum, the results demonstrate the existence of theater heterogeneity correlated with design, and most importantly, rule out the possibility that this heterogeneity is due to local demand, competition, or access to better movies. (3) The impact of scale is estimated over a quasi-continuum range of values, and although unobserved variables may explain the level of the estimated returns, it is unlikely that it also explains changes in these returns. (4) In the case of the Imax revenue premium, we confirm the estimated effect using an interaction approach that leverages (within-theater) time variations in Imax movie supply.

4 Results

Section 4.1 presents the results of the estimation of equation 4 using Cobb-Douglas, translog, semi-parametric, and piece-wise Cobb-Douglas. Through trial and error, we find that splitting theaters into six subgroups and estimating a Cobb-Douglas relation for each subgroup, delivers a good approximation of the impact of auditorium and seat on revenues. Section 4.2 report the decomposition introduced in equations 2 and 3 for the six subgroups of theaters. Section 4.3 demonstrates that the main insights of the analysis are robust to the definition of subgroups and survive a battery of robustness tests.

4.1 Theater characteristics: auditorium, seat, and Imax

Table 2 reports the results of the estimation of equation 4. All specifications include dummy variables for Imax, specialty, 3D, VIP, and couple, as well as 143 city, 20 quarter, 48 chain, and 57 age fixed effects, and report cluster-robust standard errors using market-quarter clusters.[10] According to Column 2, there are large returns to adding auditoria, decreasing returns to adding seats, and a large return to having an Imax auditorium. We reject the hypothesis of theater design neutrality.

Result 1. *Theater design neutrality (Hypothesis 1a and 1b) does not hold for the entire sample of theaters.*

Column 3 reports the coefficient estimates of a translog specification to explore Hypothesis 2 and 3. The quadratic terms for auditoria and seats are negative and significant, indicating that returns decrease with scale. The interaction term is positive and significant suggesting that auditorium and seat are complement.

[10] We tried different clustering options (no cluster, market, theater) with no significant changes in the results.

Result 2. *Hypothesis 2 and 3 do not hold for the entire sample of theaters.*

The Cobb-Douglas and translog specifications in Column 2 and 3 impose strong functional form assumptions, of constant elasticity in the Cobb-Douglas case, and linear elasticity in the translog case. These assumptions are required to hold over a wide range of auditoria and seating capacities. The next step is to explore general and tractable functional forms. We start with semi- and non-parametric returns.

4.1.1 Non-constant returns in auditorium and seating

We estimate a general specification using non-parametric dummies for auditorium count and a semi-parametric function for seat count as defined in Section 3.2. Specifically, we estimate coefficients $\beta_{a,k}$ for the auditorium count dummies and a non-linear relation between the logarithms of revenue and seat count using Robinson double residual semi-parametric regression estimator (Verardi and Debarsy, 2012). This specification controls for the same set of variables as in Table 2, and compute robust standard errors using theater level clusters. Figure 1 reports the normalized revenue elasticities to auditorium count, $\eta_a^R - 1$, and Figure 2 plots the estimate of log revenue against log seat count.

According to Hypothesis 1a, the normalized elasticities for auditorium count should be equal to zero ($\eta_a^R = 1$). Figure 1 shows that this is not the case for theaters with less than 9 auditoria. There are very large return to adding the second to fourth auditoria, with normalized elasticities equal to 1.32, .98 and 1.69 respectively. Beyond that, the return of adding theaters is still positive, although smaller, up to the ninth auditorium. The normalized elasticities are equal to .41, .68, .82, .36 and .39 respectively, and jointly significant, with a p-value of .1 percent. From the tenth auditorium and above, there is no additional return to adding auditoria. We cannot reject the hypothesis that the normalized elasticities are equal to zero (individual and joint test), and conclude that there is constant return to scale from the tenth auditorium onwards (Hypothesis 1a holds).

Result 3. *There are increasing returns to adding auditorium that are declining up to the tenth auditorium, after which there are constant returns.*

Result 3 shows that theater scale matters at the theater level. This comes in addition to theater scale making a difference at the chain level as pointed out by (Eliashberg, Elberse, and Leenders, 2006): “The exhibitor’s key power bases appear to be the total number of screens it owns, their location, and the relative shortage (or surplus) of screens available”. Moreover, the explanation for the increasing return to auditorium count within a theater cannot be bargaining power between distributors and exhibitors, because the specification reported in column 2 controls for chain fixed effects.

Turning to seat count, the revenue elasticity is the slope of the solid black curve plotted on Figure 2. To estimate this slope, we approximate the semiparametric curve with a quadratic polynomial, also plotted on Figure 2, and use Hardle, Mammen, et al. (1993) specification test statistic to check that the nonparametric fit can be approximated by a polynomial fit. We reject this hypothesis for a polynomial fit of order two or three and this is probably because the non-parametric estimation is unstable for large values of s, which could be due to the presence of unobserved heterogeneity for the subset of large auditoria. That being said, the fit is very close for the large majority theaters.[11]

The dashed line on Figure 2 has a slope of one representing a relation with constant returns. Note that the estimated relation is slightly steeper than the dashed line, indicating small increasing returns for small auditorium. This is confirmed by the derivative of the quadratic approximation plotted on Figure 3, although we cannot reject the hypothesis of constant return, since the value 1 lies in the 95% confidence band for small seating capacities. As capacity reach the level of 107 seats, we have constant return, and decreasing returns beyond that level. It's only once capacity reaches 124, however, that the hypothesis of constant return is rejected at conventional level.[12] For capacity of 276 seats, the slope is equal to zero, and we reject the existence of positive returns at the 5 percent level for capacities of 403 seats or more.

Result 4. *There are constant returns to adding seats up 124 seats per auditorium, decreasing returns from 124 to 403 seats, and negative returns beyond that level.*

Overall, the translog and non-parametric specifications give similar results. From the latter specification, we conclude that the theater design that maximizes revenue has 9 or more auditoria and no more than 124 seats. The translog coefficient estimates deliver a revenue maximizing auditorium count of 17 and seating capacity of 128, with confidence intervals 13-21 and 115-143 respectively.[13]

Based on Results 3 and 4, and on the results from the translog specification, we split theaters along two dimensions, to end up with six non-overlapping subgroups of theaters: We create (a) three subsets of theater complexes (1-4 auditoria, 5-9 auditoria, 10 and more auditoria), which we respectively call quadriplex, multiplex and megaplex; (b) and

[11]On Figure 2, the semi-parametric and parametric curves cross at 5.502, corresponding to a capacity of 245 seats, and only 6.63% of the observations are located to the right of that point, beyond which the two curves start to diverge.

[12]The upper bound of the 95% confidence interval crosses the horizontal line $y = 1$ at the value 4.82, which corresponds to 124 seats.

[13] These values solve the linear system that sets the two elasticities equal to one.

two subsets of seating capacity around the 124 threshold, and we call the theaters with 124 and fewer seats, minihall, and those with more seats, palace. The smallest theaters are quadriplex minihall and the largest are the megaplex palace. The rest of this paper uses these six subgroups to compute returns within-groups, and to conduct within-group decompositions. The robustness section demonstrates that the main results do not change when we change the thresholds used to define the six subgroups of theaters.

4.1.2 Interactions between auditorium and seat counts

Column 3 of Table 2 includes a dummy for each of the six subgroups of theater and interact the auditorium and seat count variables with each group dummy, in order to estimate the return to auditorium and seat count within group, reported in Table 3. Table 8 in the Appendix reports formal tests of Hypotheses 1-3 for the six subgroups of theaters.

For all three types of theater complexes, revenue decreases from adding seats in palace which is consistent with Figure 2. For minihall, however, the constant returns displayed on Figure 2 were hiding differences between megaplex (increasing returns) and smaller theater complexes (constant return). For all three types of theater complexes, revenues per seat peaks somewhere around the intermediate capacity of 124 seats per auditorium. Turning to auditorium, it is optimal to add auditoria to all theaters but for megaplex palace, for which we cannot reject the Hypothesis 1a of constant returns. Again, Figure 1 was hiding important differences for megaplex theaters: constant return holds only for theaters with large auditoria.

We find evidence in support of complementarity between auditorium and seat count for quadriplex and multiplex (Hypothesis 3). Table 8 in the Appendix rejects 4 out of 6 of the tests of independence, with 3 cases showing evidence of complementarity: (a) the return to additional seats is larger in bigger theater complex in two out of four tests and equal in the other two tests,[14] (b) the return to additional auditorium is larger in palace than minihall for quadriplex, the same for multiplex, and smaller for megaplex.[15]

Result 5. *Auditorium and seat are complement for quadriplex and multiplex.*

This finding is consistent with the positive interaction coefficient in the translog specification with the caveat that we find no evidence of complementarity in large theater complexes when we use the more flexible piecewise Cobb-Douglas specification.

[14]We reject $1.185 = 1.739$ and $0.058 = 0.510$.

[15]We reject $2.151 = 2.3984$ and $1.456 = 0.904$.

4.1.3 Imax premium

Column 2-4 in Table 2 reports an Imax revenue premium in the range of 44-45% and this is after holding constant all observable theater characteristics and various ways to control for theater scale (auditorium and seat count). The Imax premium does not change when we control for non-constant scale effects and interaction effects. When we allow for the Imax premium to vary over years, we find large variations, from a low of 30% to a high of 70% over the 5 years in the sample. This suggests that the Imax premium involves risks that are likely associated with the popularity of Imax movie releases as we will argue below.

Result 6. *Imax theaters earn a 45% revenue premium on their regular auditoria.*

One may argue that the 45% figure is too large because equation 4 does not include the Imax auditorium in the auditorium count variable that is used to control for theater scale. A back of the envelope calculation puts this concern to rest: Imax theaters have on average 8.28 regular auditoria, and adding the Imax auditorium increases this count by 12%. Using coefficient estimate $\beta_s = 1.95$ from specification 2 in Table 2, we obtain that an additional auditorium increases revenue by $12(\beta_s - 1) = 11\%$, which represents a little less than a quarter of the Imax revenue premium, putting a more conservative value of the Imax premium at 34%. Stated differently, the return of adding an Imax auditorium is about four times higher than the return of adding a regular additional auditorium. We conclude that an Imax theater is not the same as a regular theater with one additional auditorium.

The 45% Imax premium should be interpreted with care because Imax theaters may differ from regular theaters in other (unobservable) ways than just having an (observable) Imax auditorium. Two arguments go against this concern of unobserved heterogeneity bias. Appendix 2.4 leverages a small dataset on theater construction costs that shows no evidence that building costs are significantly higher for Imax theaters. This suggests that costly unobserved attributes used only in Imax theaters is unlikely to be the main explanation for the Imax premium.

Another way to tackle the issue of unobserved heterogeneity is to demonstrate that the Imax spillover increases when Imax movies are doing relatively well. That is, Imax theaters earn higher revenues from their regular auditoria when the Imax auditorium draws large crowds. The point is to compare identical Imax theaters across years, thereby eliminating the concern of unobserved heterogeneity. To implement this idea, we define the variable *Imax release* as the fraction of Imax movies released in a year relative to all movie released that year. We hypothesise that the Imax premium is higher when there are disproportionally more Imax movies relative to regular ones. Column 5 in Table 2 adds the variable *Imax release* alone and interacted with whether the theater has an Imax auditorium. As expected we find no statistically significant relationship for the variable alone, but a positive and statistically significant relation when interacted with the Imax dummy. An increase in the relative fraction of Imax movie releases confers positive spillovers on regular auditorium revenues.

Result 7. *The Imax premium increases when more Imax movies are released relative to regular ones.*

The percentage of Imax movies released per year varies between 6.9% to 9.2% in the sample period, contributing to a 20.5% change in the Imax premium between the worst to the best year in terms of relative Imax movie release, which represents about half of the 40% range of variation (from 30% to 70%) in Imax premium during the 5 years in the sample. This suggests that Imax spillovers largely depend on the success of Imax movies.

4.2 Decompositions

Table 9 in the Appendix reports the estimates of equation 4 using the logarithm of i, u and p as LHS variables. These estimates are used to compute the 13 decompositions in equations 2 and 3. The first 12 decompositions, corresponding to the auditorium and seat elasticities, are reported in Table 4 separately for the 6 groups of theaters, and Figures 4 and 5 offer visual representations. The Imax decomposition is discussed at the end of this section.

Adding an auditorium has a large and positive effect on seating occupancy rate that decreases with the size of the theater complex. The effect is large in both minihall and palace, although a little smaller in the latter case. Doubling the number of auditoria increases occupancy rate by 70-80% for quadriplex and to 30-50% for megaplex. An explanation is that consumer value choice once they arrive at the theater because they do not decide what movie to watch till then. Consistent with this view, Eliashberg, Elberse, and Leenders (2006) argue that "Theater circuits have begun efforts to induce more consumers to adopt the theater-first-movie-second heuristic".

Adding auditorium also has a large effect on screening intensity in small theater complexes, but this effect declines quickly as the number of auditorium increases, and becomes negative in large theater complexes (in Figure 4, $\eta_a^i = .4, .6$ for quadriplex and $\eta_a^i = -.3, -.5$ for megaplex).[16] Overall, the positive effect of adding auditorium in

[16]Note that these values of η_a^i still imply that total theater screenings increase with complex size, since the elasticity of theater screening to auditorium count is $1 - \eta_a^i \geq 0$.

megaplex on occupancy rate is cancelled out by the negative effect on screening intensity. Finally doubling the number auditora increases ticket price by about 10%.

Result 8. *(a) Occupancy rate increases at a decreasing rate with auditorium count. (b) Screening intensity contributes positively to the increasing return to auditorium in small theater complexes and negatively in large ones. (c) Adding auditoria has a small positive effect on ticket price.*

Why is screening intensity higher in multiplex? Several mechanisms could be at play. To start, there are a fixed cost associated with having longer opening hours, that may increase with theater scale. In addition, Swami (2006) and Eliashberg, Hegie, Ho, Huisman, Miller, Swami, Weinberg, and Wierenga (2009) have argued that screening more movies generates valuable information that can be used to optimize movie scheduling and the matching of movie titles to local demand. This interpretation would be consistent with the positive effect of auditorium count on screening intensity in small theater complexes. The negative effect in megaplexes, however, may be explained by demand saturation.

Adding seats to auditoria increases screening intensity in minihall but has no effect in palace. Adding seats to minihall has a mixed impact on occupancy rates, which depends on the size of the theater complex: it increases occupancy rate by about 40% in megaplex and decreases it by 20% in quadriplex. In palace, however, increasing auditorium size has a consistently large and negative impact on occupancy rates. Adding seats has a very small effect on price and this holds for all theater groups. Overall, the driving forces for revenue to peak at an intermediate capacity of about 124 seats is an increase in screenings for minihalls, and a reduction in capacity utilization in palace.

Result 9. *(a) Adding seats to minihalls increases screening intensity. (b) Doing the same in palace has a significant negative impact on occupancy rates.*

Result (9b) suggests that the average viewing experience decreases in large auditoria. Increasing seating capacity has two main effects on demand: (i) It increases the average seating distance to the screen. (ii) This, however, can be compensated with a larger screen and better projection and audio technology (Rao and Hartmann, 2015).[17] The quality effect is dominated by the distance effect for large theaters, presumably because technology cannot keep up with distance, with the nuance that the negative effect of adding seats on occupancy rates is larger in quadriplex than in megaplex, and this holds independently of the auditorium size, suggesting that the latter are better able to compensate for the distance effect with better technology.

[17] The average viewer's experience is what determines demand if consumers do not know which seat they get.

Comparing the magnitude of the three components in the 12 decompositions, occupancy rate plays the largest role and ticket price the smallest (the red rectangles are large and the green ones small in Figures 4 and 5), which is consistent with the literature showing that ticket prices vary little within and across theaters (Orbach and Einav, 2007). Our contribution is to show that although theater design has a significant impact on theater demand and revenues, theaters do not adjust prices in response to theater characteristics. The case of screening intensity is more complex. It increases at small scales (adding a seat to a small auditorium or adding an auditorium to a small theater complex increases screening intensity), but this is not the case for theaters with many auditorium or large seating capacities. This suggests that increasing consumer choice, by increasing screening intensity, is more beneficial in small theaters, as would be expected if demand saturation is an issue in large ones.

We conclude with the decomposition of the Imax premium. Recall that adding an Imax auditorium to a regular theater, making it an Imax theater but keeping theater design otherwise the same, increases the revenues from regular auditoria by about 45%. Plugging the coefficients from Table 9 in decomposition 3, we obtain:

$$\underbrace{\eta_I^R}_{44.5} \approx \underbrace{\eta_I^i}_{5.8} + \underbrace{\eta_I^u}_{26.0} + \underbrace{\eta_I^p}_{12.2} \tag{5}$$

About 60% of the Imax premium is explained by a higher seat utilization rate and almost one third by a higher Imax price premium. Adding an Imax auditorium has a small positive effect on screening intensity.

Result 10. *About two-third of the Imax premium is attributed to an increase in capacity utilization and the remaining one third is attributed to an increase in ticket price.*

Imax theaters are more efficient at using their fixed capacity: they have more 'bum on seats' for each screening and charge a price premium. This suggests that the Imax premium is largely taking place through a demand shift (a greater ability to fill seats and a premium on the price of tickets for regular auditoria), rather than a change in operations (screening intensity). Adding an Imax auditorium may not have a direct effect on the scheduling of regular movies because most regular movies cannot be played on the Imax auditorium, and similarly, many Imax movies are exclusive to the Imax auditorium.

4.3 Robustness

Table 5 and 6 explore a number robustness scenarios. For the sake of exposition, we report only the elasticities for the six subgroups of theaters, and we do so separately for auditorium and seating capacity. Specifically, the robustness scenarios are:

1. Table 5 consider 4 alternative classifications of theaters with different seating capacity thresholds. The coefficient estimates are stable with the rare exception of increasing returns to auditorium for megaplex palace in one classification.

2. Table 6, Column 1 and 2 replace the 3 miles radius for local market with 1 and 5 miles radius respectively.

3. Table 6, Column 3 controls for Imax local market by replacing the 143 city fixed effects with 400 'Imax local market' dummies that define an Imax local market as all classic theaters located within 3 miles that are closer to that Imax than to any other Imax.[18]

4. Table 6, Column 4 restricts the sample to classic theaters only, excluding Imax ones. Again, we find increasing returns to auditorium for megaplex.

Robustness checks 1-3 in Table 6 show that the results are robust to the definition of local markets. Specification 1-2 show that the results are robust to the radius used to define the geographical reach of local competition. Specification 3 addresses the concern that the 143 city dummies may not properly control for differences in local tastes or competition. Specification 4 demonstrates that the results are not driven by Imax observations.

5 Some economics of movie exhibition

This section uses the estimated revenue function to derive the profit maximizing design and assess whether theaters adopt the optimal design, distinguishing theaters built in different time periods.

5.1 Theater design: auditorium count and size

To derive the optimal auditorium count and size, we consider a theater chain that chooses the number of theaters to build, the number of auditoria per theater, and the number of seats per auditorium. The theater chain has budget K to build N theaters, with a auditoria each, and s seats per auditorium. The costs of opening a new theater is p_N and of

[18] A classic theaters that is within 3 miles of 2 or more Imax, for example, is matched to the Imax that it is closest to. This addresses the concern that the initial sample is not balanced because Imax theaters within a city may not have the same number of classic theaters nearby (see Table 11 in Appendix 2.5).

adding an auditorium to an existing theater is p_a. The cost of adding a seat is normalized to one without loss of generality. These costs include both annualized building costs and variable operating costs. A theater with a auditoria and s seats earns revenue $R(a, s)$. The chain maximizes $NR(a, s)$ subject to budget constraint $Np_N + Nap_a + Nas \leq K$. The problem is well defined in our application and a first order approach delivers two conditions that must hold at the optimum[19]

$$\eta_a^R = \frac{a(s + p_a)}{p_N + a(p_a + s)} \;\; and \;\; \eta_s^R = \frac{as}{p_N + a(p_a + s)}. \tag{6}$$

For example, when the seat cost is 90 percent of the cost of seat and auditorium, $s = .9(s + p_a)$, and the cost of seat and auditoria is 90 percent of the total theater cost, we obtain $\eta_s^R = .81$ and $\eta_a^R = .9$. More generally, equation 6 implies $\eta_a^R = \eta_s^R \frac{s+p_a}{s}$ and the following inequalities:

Hypothesis 4. *The profit maximizing scale of a theater chain is such that* $\eta_s^R \leq \eta_a^R \leq 1$.

According to Table 3, only palace megaplex satisfy the inequalities stated in Hypothesis 4, and this subgroup of theaters represent only 7.5% of all theaters.[20] Quadriplex and multiplex, covering all theaters with 9 or fewer auditoria and accounting for 87.9% of all theaters, violate inequality $\eta_a^R \leq 1$. We reach the same conclusion that theaters have too few auditoria when we use the predicted distribution of elasticities from the translog model, plotted on Figures 6 and 7.

Regarding seating capacity, condition $\eta_s^R \leq 1$ says that auditoria cannot have too few seat, likely not less than 124 according to Table 3. On the other hand, auditoria cannot have too many seats either, at least under realistic auditorium costs. To see why, rewrite equation 6 as $\frac{p_a}{p_a+s} = 1 - \frac{\eta_s^R}{\eta_a^R}$, where $\frac{p_a}{p_a+s}$ is the cost increase required to transform an auditorium of s seats into two smaller auditoria with the same total number of seats. Roughly, this is the cost of adding a separation, a projector and a screen. For example, the choice could be between a theater with 8 auditoria of 120 seats and another with 7 auditoria of 137 seats. We have $\frac{p_a}{p_a+s} \geq .5$ for all cells in the top line of Table 3 corresponding to palaces. This says that transforming an auditorium into two smaller ones would increase costs by at least 50% which is unrealistically high. We conclude that all palaces, which represent 66% of all theaters, have too large auditoria.

[19]The terms on the right hand side of equation 6 weakly increase with a or s, and when the revenue elasticities are decreasing with auditorium and seat, as is the case in our application, the optimization problem has a single optimum.

[20]Even in the case of palace megaplex , we have $\eta_a^R = 1$ with the surprising implication that the fixed theater cost is zero ($p_N = 0$).

Result 11. *The majority of theaters have too few auditoria and too many seats per auditorium.*

Figure 8 plots the distribution of theater scale using a bubble scatterplot and a grid of 10 seats and 2 auditoria. The figure reveals that most theaters have 8 or fewer auditoria (violating inequality $\eta_a^R \leq 1$) and most of these theaters have relatively large seating capacities (implying unrealistic high values for $\frac{p_a}{p_a+s}$).

5.2 Change in theater design over time

Building a new theater is a long term commitment and the choice of design is irreversible. At the same time, the optimal theater design at any given point in time depends on the available exhibition technology, and expectations about future movie supply, substitutes, and how to best deliver movies to audiences. A theater built in the 90s, for example, should adopt the optimal design that corresponds to the expected conditions that prevail in that period. With that in mind, it is important to note that the revenue elasticities used to compute the optimal theater design were estimated using data from 2012 till 2016, while most theaters in the dataset were built prior to 2012. This could explain why hypothesis 4 does not hold for the average theater in the sample. The theaters with few but large auditorium, for example, may have been built at a time when few movies were released each year and a single large auditorium was the most effective way to deliver these movies to audiences. We address the possibility that the optimal theater design has changed over time in three different ways.

To start, we show that there are significant changes in theater design over time as would be expected if demand and supply conditions change. We compute the share of the variance in auditorium count and seating capacity that is explained by year fixed effects. Year fixed effect explain 9% of the total variations in theater design for auditorium count and 22% for seating capacity. Including market and chain fixed effects increases these shares to 33% and 32% respectively, and this is despite the fact that our sample has only 5 years. Year fixed effects play a large role in explaining variations in auditorium count across observations and the most important role in the case of variations in seating capacity.

Next, we investigate whether the theaters recently built have more auditoria and fewer seats. Figures 9 plots summary statistics for auditorium count of newly built theaters and Figure 10 does the same for seating capacity. Auditorium count steadily increases, and seating capacity decreases, with the average theater having 11% more auditorium, and 37% fewer seats, in 2016 than in 2002. These trends are consistent with theaters adopting new designs over time. In addition, the fraction of newly built quadriplex-palace, the worst possible design according to the analysis, has decreased from 17% prior to 2012 to 5% after 2012.

Result 12. *Recently built theaters have more auditoria and fewer seats per auditorium.*

Third, the number of new movies released each year, arguably a key supply driver that disproportionally benefits large theater complexes, has increased significantly over time. The number of movies released in China has been slowly increasing from 2006 till 2010, and increased by more than fivefold between 2010 and 2017, with an average growth rate in years 2006-2017 of 20%.[21] This increase in movie supply is consistent the large auditorium elasticities estimated during our sample period.

To sum up, the evidence shows that theater design changes over time, and the theaters build in 2012-2016 better fit the optimization conditions that prevailed in that period than the theaters built prior to that period. Theater chains adapt theater design to match changes in demand and supply conditions, and the large increase in movie supply over the past 20 years, has probably shifted the optimum theater design toward a megaplex with intermediate seating capacity. That being said, the observed changes in theater design are relatively small. The variance decompositions, as well as Figures 9 and 10, show that many different designs are adopted at any given point in time. In addition, it is difficult to reconcile the large Imax premium with the low levels of Imax adoption.[22] This mixed evidence may be due to the fact that theater design is an irreversible investment involving large risks. Taking Imax as a case in point, Section 4.1.3 has shown that the Imax premium varied from year to year.

6 Conclusions

We strongly reject the hypothesis of theater design neutrality. We find instead large increasing returns in revenue to adding auditoria up to 9 auditoria, and to adding seats up to an intermediate seating capacity of about 120 seats, beyond which decreasing returns prevail. In addition, there is a significant revenue premium to having an Imax auditorium. The source of these deviations from theater design neutrality are explained by differences in, by order of decreasing importance, capacity utilization rates, screening intensities, and ticket prices.

[21] Entgroup report entitled "Research Report on China Film Industry 2015-2016."

[22] The fraction of newly build theaters that include an Imax auditorium has decreased up to 2011, after which it has sharply increased, to reach 6% in 2016.

Although this work has pointed to mechanisms that could explain deviations from theater design neutrality, a detailed investigation is left for future research. In the case of auditorium size, we have argued that a plausible explanation for the revenue maximizing seating capacity around 120 seats is that theaters balance the negative effect of auditorium size on the average distance-to-screen with better sound and projection technologies, but can do so only up to a point. The case of auditorium count is more complex because several forces could operate simultaneously. To start, the audience benefits from having more choice under the "theater-first-movie-second" hypothesis that confers an advantage to large theater complexes (Eliashberg, Elberse, and Leenders, 2006). At the same time, a larger theater can schedule more movies per day in order to gather valuable information that is used to optimize the matching of a growing supply of movie titles to unknown local demands (Swami, 2006). Studying the inter-dependence of theater design, movie supply, and movie scheduling is a promising topic for future research.

Although we have presented pieces of evidence that are consistent with these mechanisms, the main point of this work is to demonstrate and quantify, the importance of theater differentiation through theater design, and to propose revenue decompositions to assess the role of the screening intensity and capacity utilization channels. In doing so, this research identifies some interesting differentiation forces between movie exhibitors, but leaves important questions for future research, such as, for example, exploring the ultimate determinants of the Imax revenue premium.

Clearly, the present results are not definitive and it will be important to challenge the robustness of the methodology adopted in this work. Another limitation is that our data has forced us to focus on theaters' average seating capacity, leaving outside our reach an analysis of the diversity of auditorium size within a theater. This work has also revealed some puzzles such as the slow adjustment toward the optimal theater scale and the relatively small entry response of Imax theaters despite a large Imax premium. Opening a new movie theater involves large, long-term, and irreversible investments, with significant financial risks associated with the choice of theater design. The recent increase in movie titles in China has probably tilted the balance toward the megaplex model with intermediate size auditoria. It will be interesting to study how new theaters continue to adapt design choices in response to changes in movie supply and exhibition technology.

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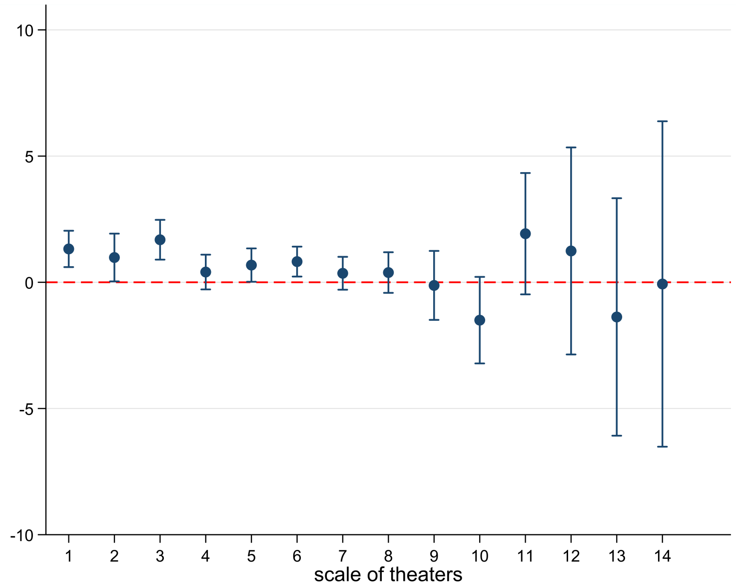
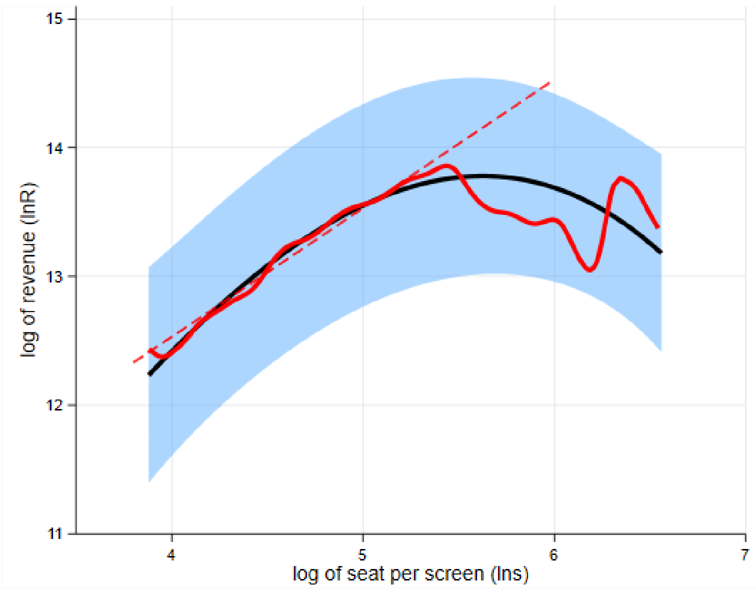
7 Figures and Tables

Figure 1: Normalized auditorium revenue elasticities



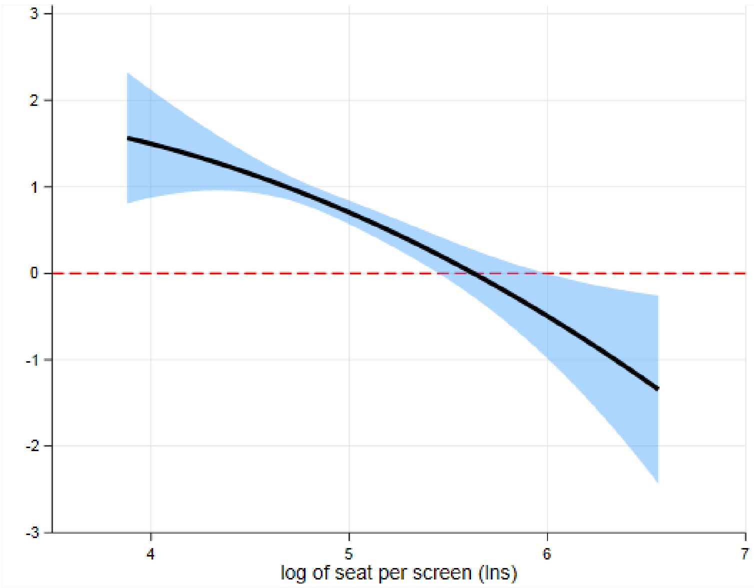
Note: The figure plots $\eta_a^R = \frac{\beta_{a+1}-\beta_a}{ln(a+1)-ln(a)} - 1$, for $a = 1 \sim 15$, with 95% confidence intervals.

Figure 2: Impact of seat count on revenue (log-log scale)



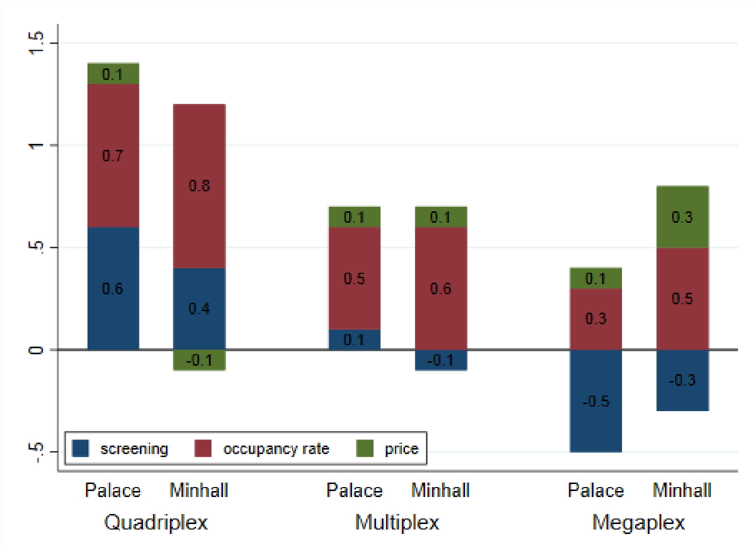
Note: The red curve plots the semi-parametric estimate, the black curve a cubic parametric fit with 95% confidence interval, and the dotted line a 45% line.

Figure 3: Seat count revenue elasticity η_s^R



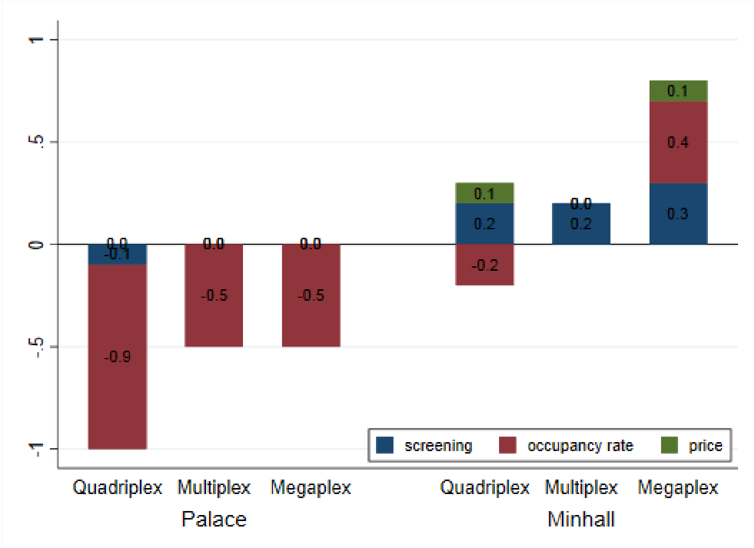
Note: The black curve plots the derivative of the cubic parametric fit from Figure 2 with 95% confidence intervals.

Figure 4: Decompositions of normalized auditorium elasticities



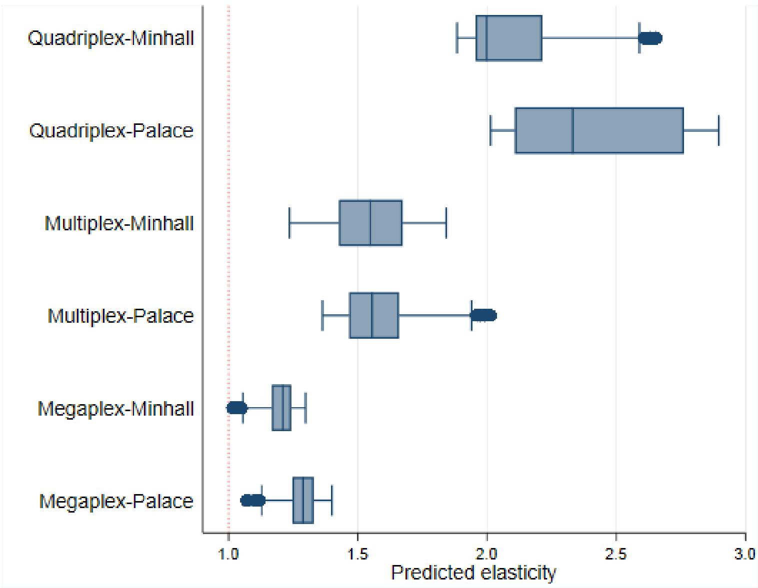
Note: Decompositions presented in equation 2, applied to the 6 theater subgroups, and using coefficients from Table 4.

Figure 5: Decompositions of normalized seating capacity elasticities



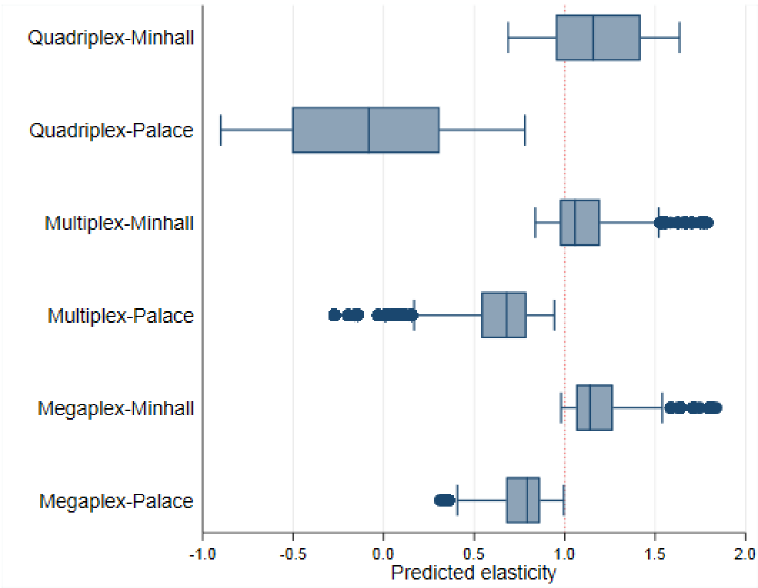
Note: Decompositions presented in equation 2, applied to the 6 theater subgroups, and using coefficients from Table 4.

Figure 6: Predicted auditorium elasticities



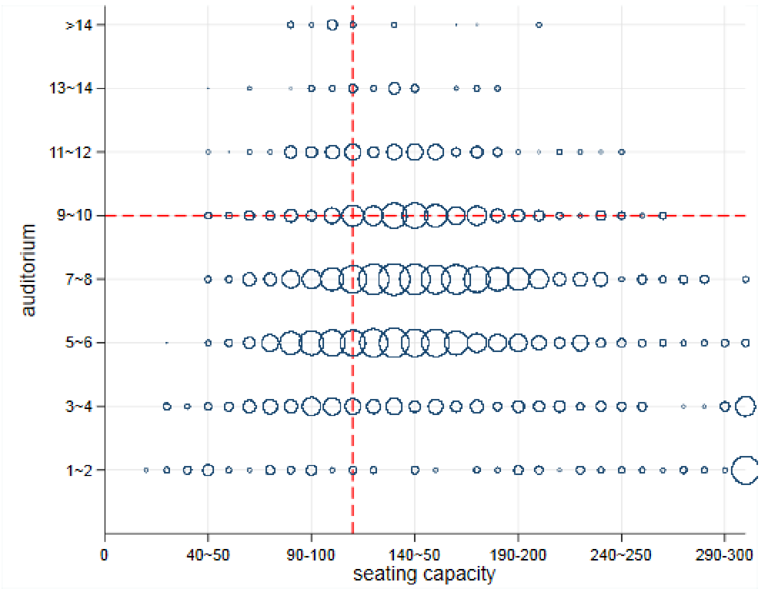
Note: Predicted values from the translog model (specification 3 in Table 2).

Figure 7: Predicted seating capacity elasticities



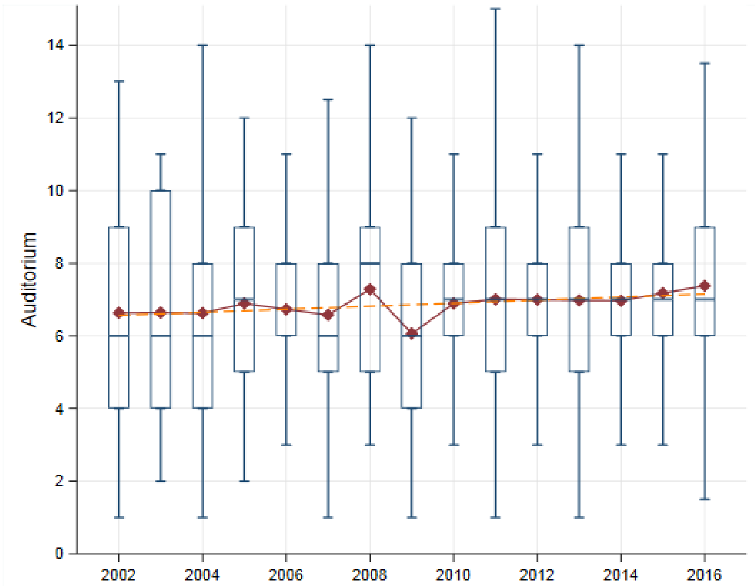
Note: Predicted values from the translog model (specification 3 in Table 2).

Figure 8: Theater scale (a, s) density



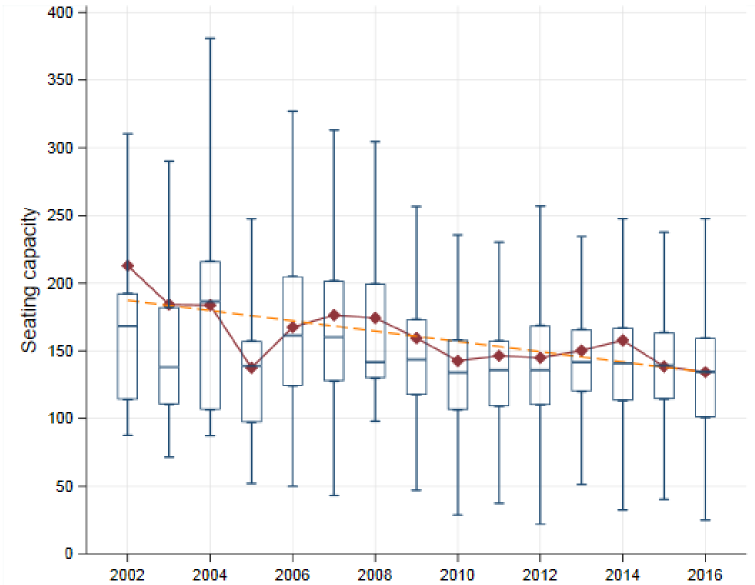
Note: Bubble scatterplot for all 24K observations, using a grid of 10 seats and 2 auditoria.

Figure 9: Auditorium count (2002-2016)



Note: Red diamonds plot mean values and the dotted line a linear approximation.

Figure 10: Seating capacity (2002-2016)



Note: Red diamonds plot mean values and the dotted line a linear approximation.

Table 1: Summary statistics of key variables for classic and Imax theaters

Variable	Mean	SD	Min	Median	Max	N
All theaters and all auditoria						
R	3,234.26	3,245.56	0.00	2,256.40	26,880.75	24,086
a	6.95	2.69	1	7	16	24,086
$a * s$	1,062.97	500.83	15	1,009	3,020	24,086
i	486.58	145.30	0.25	524.86	1,274.75	24,086
u	0.17	0.10	0.00	0.16	0.83	24,086
p	31.33	7.83	0.01	29.36	134.94	24,086
$3D$	0.99	0.12	0	1	1	24,086
VIP	0.35	0.48	0	0	1	24,086
$COUPLE$	0.12	0.32	0	0	1	24,086
$SPECIALTY$	0.93	0.26	0	1	1	24,086
Classic theaters						
R	2,520.51	2,529.96	0.00	1,807.91	26,880.75	19,984
a	6.47	2.56	1	6	15	19,984
$a * s$	951.69	449.41	15.00	908	3,020	19,984
i	476.17	145.99	0.25	515.57	1,274.75	19,984
u	0.16	0.10	0.00	0.14	0.83	19,984
p	30.19	7.27	0.01	28.45	134.94	19,984
$3D$	0.98	0.13	0	1	1	19,984
VIP	0.30	0.46	0	0	1	19,984
$COUPLE$	0.12	0.33	0	0	1	19,984
$SPECIALTY$	0.92	0.28	0	1	1	19,984
Imax theaters (regular auditoria only)						
R	5,738.71	3,565.40	0.04	5,056.42	23,477.00	4,102
a	8.27	2.05	2	8	15	4,102
$a * s$	1,235.88	352.54	287	1,217	2,543	4,102
i	537.27	130.54	4.29	559.64	925.00	4,102
u	0.23	0.09	0.00	0.22	0.70	4,102
p	36.86	8.05	18.67	35.52	77.32	4,102
$3D$	1.00	0.02	0	1	1	4,102
VIP	0.64	0.48	0	1	1	4,102
$COUPLE$	0.10	0.30	0	0	1	4,102
$SPECIALTY$	0.99	0.12	0	1	1	4,102
Imax theaters (Imax auditorium only)						
R	972.78	1,175.47	0.00	693.60	9,323.10	4,102
s	369.20	71.96	30	372	648	4,102

Note: Variables (R, a, s, i, u, p) are defined in equation 1 (Section 2.3).Control variables are defined in Section 3.3

Table 2: Return to theater design (equation 4)

lnR	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
I	0.704***	0.451***	0.445***	0.441***	-0.270*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.059)
$SPECIALTY$	1.571***	0.694***	0.399***	0.395***	0.394***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lna		1.951***	2.000***	2.151***	2.150***
		(0.000)	(0.000)	(0.000)	(0.000)
lns		0.627***	4.962***	1.133***	1.135***
		(0.000)	(0.000)	(0.000)	(0.000)
ln^2a			-0.295***		
			(0.000)		
ln^2s			-0.448***		
			(0.000)		
$lna \times lns$			0.137***		
			(0.000)		
$ImaxRelease$					0.146
					(0.116)
$I \times ImaxRelease$					0.0892***
					(0.000)
$Quadriplex \times Palace$				4.953***	4.966***
				(0.000)	(0.000)
$Multiplex \times Minihall$				0.613	0.610
				(0.336)	(0.338)
$Multiplex \times Palace$				3.729***	3.744***
				(0.000)	(0.000)
$Megaplex \times Minihall$				-1.905**	-1.882**
				(0.028)	(0.029)
$Megaplex \times Palace$				5.619***	5.603***
				(0.000)	(0.000)
$Quadriplex \times Palace \times lna$				0.247**	0.248**
				(0.047)	(0.046)
$Multiplex \times Minihall \times lna$				-0.606***	-0.606***
				(0.000)	(0.000)
$Multiplex \times Palace \times lna$				-0.499***	-0.497***
				(0.000)	(0.000)
$Megaplex \times Minihall \times lna$				-0.695***	-0.700***
				(0.002)	(0.002)
$Megaplex \times Palace \times lna$				-1.247***	-1.239***
				(0.000)	(0.000)
$Quadriplex \times Palace \times lns$				-1.076***	-1.078***
				(0.000)	(0.000)
$Multiplex \times Minihall \times lns$				0.0512	0.0516
				(0.732)	(0.730)
$Multiplex \times Palace \times lns$				-0.624***	-0.627***
				(0.000)	(0.000)
$Megaplex \times Minihall \times lns$				0.606***	0.603***
				(0.001)	(0.001)
$Megaplex \times Minihall \times lns$				-0.681***	-0.682***
				(0.000)	(0.000)
$3D$	3.646***	2.201***	1.653***	1.747***	1.746***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VIP	0.411***	0.0477***	0.0804***	0.0870***	0.0861***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
$COUPLE$	0.106***	-0.0556***	-0.0150	-0.0153	-0.0150
	(0.000)	(0.006)	(0.450)	(0.444)	(0.452)
$Constant$	9.351***	5.304***	-4.882***	3.595***	2.525***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.010)
Observations	24,086	24,086	24,086	24,086	24,086
R-squared	0.498	0.683	0.698	0.699	0.699
Time FE	YES	YES	YES	YES	YES
Market FE	YES	YES	YES	YES	YES
Chain FE	YES	YES	YES	YES	YES
Theater Age FE	YES	YES	YES	YES	YES

p-values in parentheses computed using cluster-robust standard errors with market-quarter clusters.*** p<0.01, ** p<0.05, * p<0.1

Table 3: Auditorium and seat elasticities

	Quadriplex(a< 4)	Multiplex(a=4∼9)	Megaplex(a>9)
Palace(s>124)	(2.398↑,0.058↓) (0.000,0.000)	(1.652↑,0.510↓) (0.000,0.000)	(0.904≈,0.452↓) (0.624,0.000)
Minihall(s<124)	(2.151↑,1.133≈) (0.000,0.307)	(1.545↑,1.185↑) (0.000,0.024)	(1.456↑,1.739↑) (0.018,0.000)

The top line reports auditorium and seat elasticity estimates. Bottom line reports p-value of the test that the elasticity is equal to 1. The arrows ↑ (↓) says that revenue-per-seat increases (decreases) when the variable increases; ≈ says that revenue-per-seat remains constant.

Table 4: Decomposition of scale effects (equation 2)

		lnR			lni		lnu		lnp	
		Elasticity	p-value ($\eta^R = 0$)	p-value ($\eta^R = 1$)	Elasticity	p-value ($\eta^i = 0$)	Elasticity	p-value ($\eta^u = 0$)	Elasticity	p-value ($\eta^p = 0$)
lna	Quadriplex-Minhall	2.151	(0.000)	(0.000)	0.452	(0.000)	0.768	(0.000)	-0.114	(0.002)
	Quadriplex-Palace	2.398	(0.000)	(0.000)	0.612	(0.000)	0.722	(0.000)	0.110	(0.000)
	Multiplex-Minhall	1.545	(0.000)	(0.000)	-0.099	(0.009)	0.561	(0.000)	0.086	(0.000)
	Multiplex-Palace	1.652	(0.000)	(0.000)	0.052	(0.043)	0.513	(0.000)	0.089	(0.000)
	Megaplex-Minhall	1.456	(0.000)	(0.018)	-0.276	(0.004)	0.469	(0.000)	0.277	(0.000)
	Megaplex-Palace	0.904	(0.000)	(0.624)	-0.462	(0.000)	0.293	(0.006)	0.079	(0.004)
lns	Quadriplex-Minhall	1.133	(0.000)	(0.307)	0.160	(0.032)	-0.176	(0.055)	0.116	(0.116)
	Quadriplex-Palace	0.058	(0.450)	(0.000)	-0.124	(0.006)	-0.864	(0.000)	-0.007	(0.686)
	Multiplex-Minhall	1.185	(0.000)	(0.024)	0.177	(0.000)	0.017	(0.755)	-0.028	(0.220)
	Multiplex-Palace	0.510	(0.000)	(0.000)	-0.037	(0.144)	-0.462	(0.000)	0.011	(0.148)
	Megaplex-Minhall	1.739	(0.000)	(0.000)	0.283	(0.000)	0.379	(0.001)	0.056	(0.012)
	Megaplex-Palace	0.452	(0.000)	(0.000)	0.031	(0.708)	-0.531	(0.000)	-0.042	(0.059)

Note: Although the decompositions are not exact, the estimated absolute differences between the LHS and RHS of equation 2 are small for most decompositions with an upper bound of .053.

Table 5: Robustness checks: Definition of theater subgroups

	Type	a=1∼4,5∼9,>9 s=1∼107,>107	a=1∼4,5∼9,>9 s=1∼115,>115	a=1∼4,5∼9,>9 s=1∼128,>128	a=1∼4,5∼9,>9 s=1∼143,>143
lna	Quadriplex-Minhall	2.037	2.020	2.252	2.268
		(0.000)	(0.000)	(0.000)	(0.000)
	Quadriplex-Palace	2.460	2.476	2.301	2.291
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Minhall	1.533	1.461	1.497	1.530
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Palace	1.634	1.673	1.682	1.722
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Minhall	1.381	1.388	1.454	1.168
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Palace	0.920	0.902	0.909	1.435
		(0.000)	(0.000)	(0.000)	(0.000)
lns	Quadriplex-Minhall	1.474	1.446	0.956	0.975
		(0.000)	(0.000)	(0.000)	(0.000)
	Quadriplex-Palace	0.181	0.185	-0.077	-0.122
		(0.005)	(0.007)	(0.335)	(0.159)
	Multiplex-Minhall	1.092	1.055	1.166	1.197
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Palace	0.632	0.534	0.461	0.477
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Minhall	2.150	1.937	1.690	1.540
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Palace	0.704	0.648	0.407	0.292
		(0.000)	(0.000)	(0.002)	(0.062)

Note: The 107 threshold corresponds to the capacity where the elasticity is equal to one in Figure 3; the 128, 115 and 143 thresholds corresponds to the revenue maximizing seating capacity from the translog function, together with the 95% confidence interval values. See footnote 13.

Table 6: Robustness checks: Local market and sample definitions

	Type	Radius=1m	Radius=5m	Imax Market FE	Classic
lna	Quadriplex-Minhall	2.83	1.96	2.17	2.17
		(0.000)	(0.000)	(0.000)	(0.000)
	Quadriplex-Palace	2.35	2.37	2.47	2.45
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Minhall	1.71	1.52	1.46	1.50
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Palace	1.64	1.63	1.54	1.76
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Minhall	1.16	1.67	1.44	1.71
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Palace	0.68	1.16	0.81	1.23
		(0.009)	(0.000)	(0.000)	(0.000)
lns	Quadriplex-Minhall	0.406	1.313	1.190	1.102
		(0.046)	(0.000)	(0.000)	(0.000)
	Quadriplex-Palace	-0.028	0.192	0.133	0.108
		(0.827)	(0.001)	(0.082)	(0.167)
	Multiplex-Minhall	1.199	1.216	1.304	1.196
		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Palace	0.518	0.543	0.592	0.573
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Minhall	1.339	1.396	1.654	1.768
		(0.000)	(0.000)	(0.000)	(0.000)
	Megaplex-Palace	0.533	0.437	0.526	0.315
		(0.005)	(0.000)	(0.000)	(0.026)

Online Appendix (not submitted for publication)

1 Data appendix

1.1 Variable construction: Specialty

To create the Specialty dummy, we look into the theater's name because it reveals the type of theater. A theater that contains: (a) 'ying ju yuan' means that the theater is used to show movies and opera; (b) 'ju chang', 'ju yuan', 'concert hall' means that the main business is playing opera; 'conference center', 'conference hall', 'auditorium', 'memorial hall', 'club' means that the main business is hosting meetings and events.

1.2 Summary statistics in level

Table 7 replicates the summary statistics from Table 1 but in logarithm instead of level.

Table 7: Summary statistics of key variables for classic and Imax theaters in logarithm

Variable	Mean	SD	Min	Median	Max	N
All theaters and all auditoria						
lnR	14.27	1.62	-4.68	14.63	17.11	24,086
lna	1.84	0.50	0.00	1.95	2.77	24,086
$lna * s$	4.96	0.41	3.88	4.95	6.56	24,086
lni	6.09	0.59	-1.39	6.26	7.15	24,086
lnu	-2.05	0.91	-11.59	-1.85	-0.18	24,086
lnp	3.42	0.23	-4.68	3.38	4.90	24,086
$3D$	0.99	0.12	0	1	1	24,086
VIP	0.35	0.48	0	0	1	24,086
$COUPLE$	0.12	0.32	0	0	1	24,086
$SPECIALTY$	0.93	0.26	0	1	1	24,086
Classic theaters						
lnR	14.02	1.62	-4.68	14.41	17.11	19,984
lna	1.76	0.51	0.00	1.79	2.71	19,984
$lna * s$	4.96	0.44	3.88	4.93	6.56	19,984
lni	6.06	0.60	-1.39	6.25	7.15	19,984
lnu	-2.14	0.95	-11.59	-1.93	-0.18	19,984
lnp	3.38	0.22	-4.68	3.35	4.90	19,984
$3D$	0.98	0.13	0	1	1	19,984
VIP	0.30	0.46	0	0	1	19,984
$COUPLE$	0.12	0.33	0	0	1	19,984
$SPECIALTY$	0.92	0.28	0	1	1	19,984
Imax theaters (regular auditoria only)						
lnR	15.30	0.91	3.65	15.44	16.97	4,102
lna	2.08	0.26	0.69	2.08	2.71	4,102
$lna * s$	5.00	0.22	4.22	5.00	5.63	4,102
lni	6.22	0.51	1.46	6.33	6.83	4,102
lnu	-1.58	0.48	-9.93	-1.53	-0.36	4,102
lnp	3.58	0.21	2.93	3.57	4.35	4,102
$3D$	1.00	0.02	0	1	1	4,102
VIP	0.64	0.48	0	1	1	4,102
$COUPLE$	0.10	0.30	0	0	1	4,102
$SPECIALTY$	0.99	0.12	0	1	1	4,102
Imax theaters (Imax auditorium only)						
lnR	8.91	6.72	0.00	13.45	16.05	4,102
lns	5.89	0.20	3.40	5.92	6.47	4,102

Note: Variables (R, a, s, i, u, p) are defined in equation 1 (Section 2.3).
Control variables are defined in Section 3.3

2 Appendix: Additional results

2.1 Longitudinal variations

Theaters extremely rarely change the number of auditorium count, seat count, or Imax screen. To demonstrate this, we use unique theater locations that associate a unique latitude and longitude to each theater in the dataset. There are 8300 unique locations in the sample, out of which 8292 are matched with the same theater in all periods. Out of the remaining 8 locations that have more than one theater match, only 4 are managed by the same chain throughout the sample period, 5 have a different count of auditorium, 7 have a different count of seats, and none have a different Imax count.[23] We conclude that there is almost no longitudinal variation in theater design, and when there is, other attributes including theater chain, change together with theater design.

Gil and Hartmann (2007) reach the same conclusion that theater characteristics (number of auditoria and seating capacity) do not change over time. The fixed cost of entering the market is very high, and the depreciation period of theatre equipment is at least 5-10 years. As a result, theater exit is rare. Only 3 of the 411 Chinese Imax entrants in our sample have exited. The exit rate for classic theaters is slightly higher at about 3% per year.

2.2 Test of equality of elasticities across groups

Table 8 tests the equality of the elasticities for auditorium and seat across the 6 groups of theaters.

[23]It is possible that two theaters are located so close, e.g. in the same shopping mall, that they are matched to the same unique location, and we cannot distinguish this possibility from the alternative that there is a single theater that changed design. Thus, we conclude that *at most* 8 theaters may have changed design in the sample period.

Table 8: Test of equality of elasticities across theater groups

	Type	Elasticity	p-value $\eta^R = 0$	p-value $\eta^R = 1$	p-value for elasticities being equal				
					small-large	middle-small	middle-large	large-small	large-large
lna	Quadriplex-Minhall	2.151	(0.000)	(0.000)	(0.048)	(0.000)	(0.000)	(0.002)	(0.000)
	Quadriplex-Palace	2.398	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	Multiplex-Minhall	1.545	(0.000)	(0.000)			(0.181)	(0.662)	(0.002)
	Multiplex-Palace	1.652	(0.000)	(0.000)				(0.337)	(0.000)
	Megaplex-Minhall	1.456	(0.000)	(0.018)					(0.032)
	Megaplex-Palace	0.904	(0.000)	(0.624)					
lns	Quadriplex-Minhall	1.133	(0.000)	(0.307)	(0.000)	(0.732)	(0.000)	(0.001)	(0.000)
	Quadriplex-Palace	0.058	(0.450)	(0.000)		(0.000)	(0.000)	(0.000)	(0.006)
	Multiplex-Minhall	1.185	(0.000)	(0.024)			(0.000)	(0.002)	(0.000)
	Multiplex-Palace	0.510	(0.000)	(0.000)				(0.000)	(0.670)
	Megaplex-Minhall	1.739	(0.000)	(0.000)					(0.000)
	Megaplex-Palace	0.452	(0.000)	(0.000)					

2.3 Estimation of equation (4) with (i, u, p) as LHS variables

Table 9 reports the results of the estimation of Equation (4) using for LHS variables (i, u, p). This delivers the estimates of $(\eta^i_x, \eta^u_x, \eta^p_x)$ for $x = a, s$ and $(\eta^i_I, \eta^u_I, \eta^p_I)$.

Table 9: Estimation of equation 4 with (lni, lnu, lnp) as LHS

	(1) lni	(2) lnu	(3) lnp	(4) lni	(5) lnu	(6) lnp
I	0.0581***	0.264***	0.124***	0.0584***	0.260***	0.122***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$SPECIALTY$	0.198***	0.284***	-0.0152	0.182***	0.241***	-0.0234**
	(0.000)	(0.000)	(0.148)	(0.000)	(0.000)	(0.032)
lna	0.564***	0.801***	0.0194	0.452***	0.768***	-0.114***
	(0.000)	(0.000)	(0.255)	(0.000)	(0.000)	(0.002)
lns	0.161***	-0.0124	-0.0515***	0.160**	-0.176*	-0.0568
	(0.000)	(0.778)	(0.002)	(0.032)	(0.055)	(0.116)
$Quadriplex \times Palace$	1.194***	3.134***	-0.141	1.155***	3.565***	-0.540***
	(0.000)	(0.000)	(0.134)	(0.007)	(0.000)	(0.005)
$Multiplex \times Minihall$	0.723***	0.368***	-0.156***	0.709**	-0.584	-0.428**
	(0.000)	(0.000)	(0.000)	(0.049)	(0.195)	(0.014)
$Multiplex \times Palace$	1.985***	3.591***	-0.178**	1.436***	1.858***	-0.577***
	(0.000)	(0.000)	(0.037)	(0.000)	(0.000)	(0.000)
$Megaplex \times Minihall$	1.533***	0.495**	-0.444***	0.633	-2.164***	-1.310***
	(0.000)	(0.032)	(0.000)	(0.127)	(0.002)	(0.000)
$Megaplex \times Palace$	2.769***	3.747***	-0.440***	2.217***	2.653***	-0.296
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.106)
$Multiplex \times lna$	-0.567***	-0.273***	0.0665***			
	(0.000)	(0.000)	(0.000)			
$Megaplex \times lna$	-0.929***	-0.378***	0.173***			
	(0.000)	(0.000)	(0.000)			
$Palace \times lns$	-0.261***	-0.648***	0.0171			
	(0.000)	(0.000)	(0.394)			
$Quadriplex \times Palace \times lna$				0.160**	-0.0455	0.224***
				(0.031)	(0.602)	(0.000)
$Multiplex \times Minihall \times lna$				-0.551***	-0.206**	0.200***
				(0.000)	(0.018)	(0.000)
$Multiplex \times Palace \times lna$				-0.400***	-0.255***	0.203***
				(0.000)	(0.002)	(0.000)
$Megaplex \times Minihall \times lna$				-0.727***	-0.298*	0.392***
				(0.000)	(0.057)	(0.000)
$Megaplex \times Palace \times lna$				-0.913***	-0.475***	0.193***
				(0.000)	(0.000)	(0.000)
$Quadriplex \times Palace \times lns$				-0.284***	-0.688***	0.0494
				(0.002)	(0.000)	(0.247)
$Multiplex \times Minihall \times lns$				0.0168	0.193*	0.0285
				(0.841)	(0.073)	(0.512)
$Multiplex \times Palace \times lns$				-0.197**	-0.286***	0.0674*
				(0.014)	(0.004)	(0.065)
$Megaplex \times Minihall \times lns$				0.123	0.555***	0.113***
				(0.193)	(0.000)	(0.004)
$Megaplex \times Minihall \times lns$				-0.129	-0.355***	0.0153
				(0.237)	(0.002)	(0.707)
$3D$	1.080***	0.602***	0.118**	1.078***	0.568***	0.124***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.008)
VIP	0.0308***	0.0319***	0.0217***	0.0309***	0.0315***	0.0227***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
$COUPLE$	0.0110	-0.0237*	-0.0153***	0.0134	-0.0169	-0.0132***
	(0.309)	(0.063)	(0.000)	(0.217)	(0.182)	(0.000)
$Constant$	3.802***	-4.302***	3.962***	3.962***	-3.529***	4.161***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	24,086	24,086	24,086	24,086	24,086	24,086
R-squared	0.334	0.554	0.522	0.335	0.555	0.530
Time FE	YES	YES	YES	YES	YES	YES
Market FE	YES	YES	YES	YES	YES	YES
Chain FE	YES	YES	YES	YES	YES	YES
Theater Age FE	YES	YES	YES	YES	YES	YES

Note: p-values in parentheses computed using cluster-robust standard errors with market-quarter clusters.*** p<0.01, ** p<0.05, * p<0.1

2.4 Cost evidence

To further investigate the possibility of unobserved product attributes, we use a smaller dataset on building cost. The cost figures were collected from annual reports of cinema chains and exclude the theater property value. We observe the building cost of 106 theaters, including 29 Imax theaters, and 77 classic theaters with an auditorium count varying between 4 and 11. An indirect way to rule out unobserved product attributes is to compare the cost of classic and Imax theaters, and for classic theaters, to investigate whether cost depends on auditorium count. If Imax and larger theaters have greater amenities (e.g. parking, game arcade, or brand value), one would expect the building cost of these theaters to be higher.

We first investigate whether Imax theaters cost more to build, which would be consistent with the hypothesis that Imax offer a superior product. Table 10 reports the overall theater building cost, the cost per auditorium, and the cost per seat for both Imax and classic theaters. The cost per seat of an Imax theater is higher than for a regular theater but the difference is only 5%. The cost per auditorium is 9% higher for Imax theaters. These small cost differences can explain only a small fraction of the Imax revenue premium.

The same holds for scale. The marginal cost of an auditorium decreases with auditorium count. The incremental cost of adding an auditorium decreases by 71K CNY which corresponds to 3.8% of the median auditorium cost across all classic theaters.[24] Theater building cost displays a small decreasing return, if anything. If larger theaters had unobserved product attributes, we would expect these theaters to have higher auditorium costs, not lower ones. To conclude, the cost evidence suggest that the two main results, on theater design and Imax premium, are unlikely to be explained by unobserved product attributes.

[24] A linear regression of cost per auditorium on auditorium count, for the sample of 77 classic theaters, gives a negative slope, significant at 5 percent confidence level, with value -7.1.

Table 10: Theater cost

variable	mean	sd	p25	p50	p75	min	max	N
C	1,585.31	509.60	1,266.19	1,488.15	1,836.56	530.00	3,982.84	106
a	8.13	1.80	7	8	9	4	14	106
$a * s$	1,323.20	382.73	1,046	1,305	1,510	576.00	2,787	106
s	163.61	33.11	144.29	165.02	189.00	52.36	250.00	106
C/a	197.44	52.07	165.93	193.37	222.50	75.71	345.88	106
$C/(a * s)$	1.24	0.33	1.00	1.20	1.43	0.44	2.08	106
Classic theaters								
C	1,442.68	369.87	1,184.00	1,380.00	1,691.59	530.00	2,347.32	77
a	7.56	1.41	7	7	8	4	11	77
$a * s$	1,211.79	307.43	1,012	1,200	1,388	576	2,055	77
s	161.97	35.54	135.88	164.88	187.63	52.36	250.00	77
C/a	192.71	43.38	166.89	188.13	216.16	75.71	333.33	77
$C/(a * s)$	1.22	0.27	1.01	1.19	1.41	0.57	1.80	77
Imax theaters								
C	1,964.02	630.89	1,630.00	1,830.00	2,174.22	930.00	3,982.84	29
a	9.66	1.86	8	9	10	7	14	29
$a * s$	1,619.00	409.90	1,395	1,510	1,845	1,129	2,787	29
s	167.95	25.58	151.63	166.67	191.25	115.36	215.71	29
C/a	209.98	69.53	165.93	203.33	273.18	87.14	345.88	29
$C/(a * s)$	1.28	0.46	0.99	1.21	1.58	0.44	2.08	29

2.5 Local competition

Table 11 reports the number of classic and Imax theater competitors within 3 miles radius of (a) the average theater in the sample (first 2 lines), (b) classic theaters only (next 2 lines), and (c) Imax theaters only (last 2 lines). For example, there are 9.35 classic theaters near the average theater in the sample but only 7.75 near an Imax theater.

Table 11: Number of different types of rivals of different incumbents

	Mean	SD	p5	p25	p50	p75	Min	Max	N
Classic	9.35	6.53	1	4	8	13	0	36	24,356
Imax	1.48	1.08	0	1	1	2	0	8	24,356
Classic near classic	9.68	6.62	2	4	8	14	0	36	20,231
Imax near classic	1.64	1.01	1	1	1	2	1	8	20,231
Classic near Imax	7.75	5.82	1	3	6	11	0	35	4,125
Imax near Imax	0.70	1.05	0	0	0	1	0	6	4,125

2.6 Vertical integration

A theater chains is vertically integrated if it is owned by, or owns, a movie distributor. The *integration* dummy is equal to one if a theater is part of a vertically integrated chain, and is constructed as follows. Table 12 lists the top 10 distributors in China in 2012-2014. The China's film distribution industry is highly concentrated with the top 10 firms accounting for more than 80% of the market, and the top two accounting for more than half. We checked whether the top 10 distributors are the shareholders of any cinema chain in our sample, and vice-versa, based on the information from official websites and annual reports, to create a 'vertical integration' dummy, which equals to one if there is an ownership relation between the theater chain and its distributor, and if the distributor ranks in the top 10 in that year. Take Wanda as an example. Its distribution company was established in 2011, so Wanda is integrated in 2012, but the distribution company did not make it to the top 10 in 2012, so the vertical integration dummy is set to zero.

Table 12: Top 10 distributors in China (2012-2014)

2012		2013		2014	
Distributor	Share	Distributor	Share	Distributor	Share
China Film	38.24%	China Film	32.50%	China Film	32.80%
Huaxia	23.51%	Huaxia	17.42%	Huaxia	22.89%
Huayi brothers	10.22%	Huayi brothers	12.54%	Enlight Pictures	7.75%
Enlight Pictures	7.37%	Le Vision	3.68%	Bona Film	5.99%
Bona Film	3.34%	Enlight Pictures	3.51%	Wanda Film	5.20%
Meiya Huatianxia	2.21%	Bona Film	3.50%	Le Vision	4.10%
Le Vision	1.32%	Wanda Film	1.85%	Huayi brothers	2.26%
Xingmei Film	1.08%	Edko Film	1.50%	UEP	2%
Edko Film	1.06%	Union Pictures	1.47%	Hengye Pcitures	1.77%
Sil-Metropole	0.83%	SMG Pictures	1.21%	Anshi Yingna	1.52%
Total	89.18%		79.18%		86.28%

Table 13: Integrated chains and theaters by year

year	Chains	Intergrated	Share (%)	Theaters	Intergrated	Share(%)
2012	46	15	33	3,087	1,414	45.80
2013	47	16	34	3,923	1,870	47.67
2014	47	18	38	4,951	2,292	46.29
2015	48	18	38	6,508	2,977	45.74
2016	48	18	38	7,933	3,753	47.31
Total	236	85	36	26,402	12,421	47.05