The Hold-up Problem in China's Broiler Industry: Empirical Evidence from Jiangsu Province

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Abstract

Using detailed survey data on broiler growers, we tested for the existence of hold-up problems in the broiler industry in Jiangsu Province, China. We found that growers' investments in chicken houses, which are assets with a high degree of physical and location specificity, increased along with the number of potential buyers (integrators) nearby. Such an effect was particularly strong in proximity to leading industry buyers. These results support the existence of hold-ups in the Chinese broiler industry. However, we failed to find evidence that a longer-term contract led to higher grower investments in chicken houses, possibly because of the lack of a minimum purchase guarantee in a typical contract. A key policy implication of this study is that subsidies to growers, from the government or buyers, can alleviate the underinvestment problem caused by hold-ups.

KEYWORDS:asset specificity, broiler, buyer power, hold-up, integrator

JEL Codes*:* Q13, L13, L66

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Introduction

Asset specificity refers to the degree to which an asset's value is specific to a particular transaction relationship (Riordan et al., 1985; Williamson, 1985, 1991; Anderson and Weitz, 1992; Liu et al., 2009; Chen et al., 2015). Many types of asset specificity exist, such as site, physical asset, and human asset specificities. In the presence of asset specificity, the salvage value of an asset decreases significantly outside a specific contract. Once an investment is made, for example, by a contract grower, the contractor (the other party of the contract) may take advantage of these transaction-specific assets and engage in opportunistic behaviors to "squeeze" the investor (Hoetker and Mellewigt, 2009; Williamson, 1985). This is a well-known hold-up problem in economics literature.

Many researchers have studied the hold-up problem from different perspectives, with the majority focusing on the relationships among transaction costs, hold-up, and vertical integration (John and Weitz, 1988; Joskow, 1988; Levy, 1985; Maher, 1997; Monteverde and Teece, 1982). Another large strand of the literature has explored mechanisms for mitigating hold-ups, such as the use of long-term contracts (Joskow, 1985, 1987, 1990), open access (McCabe and Snyder, 2018), controlling the flow of information (Durand-Viel and Villeneuve, 2016; Gul, 2010; Nguyen and Tan, 2019), renegotiations (Aghion et al., 1994; Georg and Klaus, 1995), and adding more clauses to contracts (Iyer and Sautner, 2018).

Studies empirically testing for the existence of hold-ups are rare, with the notable exceptions of Beales and Muris (1995), Galetovic et al. (2015), and Vukina and Leegomonchai (2006), who provide mixed evidence. Beales and Muris (1995) found little opportunism in the U.S. franchise industry. Similarly, Galetovic et al. (2015) used a difference-in-differences approach and found no empirical support for standard essential patents in the United States holding up innovation. However, Vukina and Leegomonchai (2006) reported evidence on hold-ups based on a cross-sectional national survey of U.S. broiler growers in 1999. Chicken houses are characterized by a high degree of physical and location specificity, implying that chicken houses have very few applications besides farming chickens, and live chicken cannot be transported far. They found that the number of chicken houses that a grower operated increased along with the number of potential buyers (integrators offering contracts) in a given area. The intuition here is that more potential buyers nearby can increase the salvage value of growers' investments in chicken houses and alleviate growers' underinvestment problems.

This study's focus stems from the observation that research testing for the existence of hold-up is both limited (mostly focusing on the U.S. case) and inconclusive. Vukina and Leegomonchai (2006) noted that there is lack of empirical evidence of hold-up because contract parties know the problem and have probably already made advance arrangements to mitigate the problem. Therefore, testing for the existence of hold-up has implications for whether any such mitigation arrangement can be effective. In addition, limited data on confidential information, such as investment levels and contract details, could also contribute to this research scarcity. Accordingly, this study aims to provide insight into this issue from the perspective of cross-national comparisons.

This study provides an empirical test for the existence of a hold-up that focuses on China's broiler industry. Contract is widely used in the broiler farming industry in China; however, growers have been observed to be reluctant to invest in specific assets due to fears of accepting unfair, low prices (Huang et al., 2018; Mao et al,. 2019). Therefore, an empirical examination of the existence of hold-up can provide insight into the cause of underinvestment in the industry. Several studies have examined the nature of the hold-up problem in China, all of which focused on the aforementioned first two strands of the literature. For example, Hua et al. (2002) argued that designing a good contract governance structure could prevent hold-ups. Qian (2015) conducted an empirical analysis of loans extended to small- and medium-sized companies and found that bank competition was conducive to easing the hold-up problem between banks and companies, reducing financing costs, and easing credit risk. Ji and Qiu (2003) analyzed firm boundaries based on the hold-up problem, highlighting the impact of transaction mechanisms on firms' incentives to be honest. The present study differs from these in that it focuses on the existence of a hold-up, with a secondary objective to examine whether long-term contracts mitigate the underinvestment problem.

To the best of the authors' knowledge, this is the first study to examine the hold-up problem in China's broiler industry. This study makes two contributions to the literature. First, detailed survey data on broiler growers in Jiangsu Province for 2015 were used. Jiangsu Province ranks sixth in poultry production in China and contract farming is common in its broiler industry. As we discuss later in the data section, Jiangsu is the most advanced province in contract farming in the broiler industry, where it is the predominant method for raising chicken. Despite this fame, data from the *China Animal Husbandry Yearbook* show that the number of broiler growers in Jiangsu dropped rapidly from 468,900 in 2011 to 196,500 in 2015. Therefore, Jiangsu presents a unique case for examining whether hold-up contributed to growers' underinvestment—so much so that it possibly resulted in their exit, but we do not examine that directly here.

The survey data include detailed investment and contract information for hundreds of growers located throughout the province. These data allow empirical testing for the existence of hold-up as well as exploring potential strategies to alleviate hold-up from the perspectives of marketing channels and government. This analysis offers a unique comparison of the problem for the industry in the United States and China.

Second, we extend the underinvestment model developed by Vukina and Leegomonchai (2006) to allow for the role of the contract period. Many studies examining the role of the contract period on hold-up tend to be theoretical (e.g., Deng et al., 2014; Durand-Viel and Villeneuve, 2016) or have a focus other than the impact of the contract period. For example, Joskow (1987) examined U.S. coal markets and found that a high degree of asset specificity led to the use of long-term contracts. Data on actual contract periods allow this study to specifically test the hypothesis that long-term contracts mitigate the underinvestment problem. The next section discusses in detail the theoretical base of our study.

Extended underinvestment model

This section extends the underinvestment model developed by Vukina and Leegomonchai (2006) to allow for the role of the contract period. First, we introduce the contract farming mechanism in the Chinese broiler industry. This mechanism is largely based on actual contracts between growers and the leading integrators in Jiangsu Province. The remaining smaller integrators generally follow a similar contract mechanism, with only slight differences in the degrees of deposit, reward, and penalty.

Contract farming in China's broiler industry

The two relevant parties in contract farming are contract growers (growers for short) and broiler integrators (also known as contractors). Integrators supply baby chicks, feed, medicines, vaccines, and technical advice, and eventually acquire all grown chicken from growers. They also mandate the variety of baby chicks supplied. Growers are responsible for providing labor, housing, facilities, and utilities to raise newborn chicks to market weight. Growers can also sell to integrators through cooperatives. Cooperatives' roles are largely 1) helping integrators supervise growers to raise qualified chickens, 2) helping growers transport chicken and suppliers, and 3) facilitating price bargaining between growers and integrators (for a better price for growers). In the absence of a cooperative, growers need to bear the transportation expenses of picking up the materials provided by integrators and delivering the chicken to the designated sales platforms.

We further examine the contracts between Wen's Group Co. Ltd. (hereafter, Wen's group) and their growers. Wen's Group, a well-known listed company engaged in the farming, breeding, and marketing of broilers, chickens, and pigs, was the first to start contract farming in China's broiler industry. At ¥88 billion, it is also the largest broiler company in China based on market value. In Wen's business model, a grower first needs to apply to raise chickens. Wen's then examines whether the grower has a standard chicken house to accommodate more than 2,000 chickens. If the grower does not meet this condition, they have to sign a contract with Wen's who then provides subsidies to help build or enhance chicken houses. Shortly before receiving the baby chicks, growers need to provide a one-time deposit (earnest money) to the integrators of an amount larger than ¥10 per baby chick. The number of grown chickens delivered, plus the dead chicken the grower has registered with the integrator, should be no less than 99% of the number of supplied baby chicks. The error of this 1% is mainly due to accidental loss and death of chickens in the process of final sale. Otherwise, growers will lose 30% of the deposit (in reality, this rarely happens). The same penalty applies if growers fail to meet a delivery deadline or quality requirement (stipulated outside the contract). Chicken houses and supporting facilities are used as asset mortgages, if necessary.

The grower also receives feed, medicine, and technical manuals from Wen's at prescheduled times and can rent select equipment from the integrator. The technical service department at Wen's provides free door-to-door technical guidance to all contract growers every three days. The guidance includes vaccination, ventilation and heat preservation, feeding density, feeding cycle, drug ratio, and feeding method. Wen et al. has a consultation office for poultry disease diagnosis to provide free technical consultation. Finally, Wen's uses their information management system to manage their growers, informing the growers or the cooperatives to send the chicken that has reached maturity age to its sales department for selection and weighing. The financial department then prints a list of the market rate of chicken, the ratio of feed to meat, the average weight of chicken in the market, and so on. The growers are paid based on the above factors, excluding the cost of chicks, feed, and medicine.

Generally, contracts do not spell out the actual compensation formula. One reason is that there are many varieties of chickens within the yellow-feathered type, to be discussed in the next section, featuring different growth periods. Integrators have the right to adjust the prices of inputs and grown chickens according to factors such as growers' production performance, seasonality, industry, and market demand changes to balance growers' annual income.

Similar to most U.S. contracts in the broiler industry, Chinese contracts do not specify the number of flocks that an integrator is obliged to buy each year. Generally, growers prefer a larger number of flocks per year, for example, up to four flocks for chicken species raised in Jiangsu Province. However, the integrator does not commit to providing this but instead assigns the number of flocks depending on the market conditions and grower performance. In many cases, as discussed before, the integrator provides subsidies to growers to build chicken houses. Therefore, a longer contract period sometimes secures the use of assets as intended.

Overall, Besanko et al. (2017) conclude that bounded rationality, difficulties in specifying and measuring performance, and asymmetric information are the main factors preventing complete contracting and leading to hold-up. Using this framework, we summarize the main factors that could lead to hold-up based on Wen's contract as follows: 1) the prices Wen's sets for inputs, baby chicks, and grown chicken are not based on market prices and are subject to Wen's internal adjustments (ambiguity in measuring performance and asymmetric information since growers are not aware of Wen's internal adjustment process), and 2) Wen's also reserves the right to terminate the contract early if they find any activity by the grower damaging to their interest.

Underinvestment model with contract period

We now estimate grower's investment benefits. In general, chicken houses are the growers' biggest investments. In this model, grower's benefit from an investment is defined as $b(I)$, with, $\frac{\partial b(I)}{\partial I} > 0$, and $\frac{\partial^2 b(I)}{\partial I^2} < 0$, which captures the maximum return to the full life utilization of an investment. Assuming the marginal cost of investment is *c*, the first-order profit maximization condition leads to the optimal investment:

level $\frac{\partial b(I)}{\partial I} = c$, denoted as I*_optimal in Figure 1. In Figure 1, the benefit function curve is concave, as defined. Optimal investment occurs when the slope of the benefit function equals marginal cost.

Next, a salvage value function is introduced to model the hold-up problem. The salvage value is the value of the grower's investment if the contract does not proceed as initially planned and is therefore defined as $r(n, \lambda, I)$ with the function

$$r(n, \lambda, I) = \lambda I(1 - \frac{1}{n}), \text{ where}$$

λ is the degree of the investment's physical specificity ($\lambda \in [0,1]$), and n ($n \geq 1$) is the degree of location specificity measured by the number of integrators in a given area. When $\lambda = 1$, the investment is generic; when $\lambda = 0$, the asset is the most specific.

The model assumes that bargaining allows the grower to capture a share of the gain from contracting, which is $b(I) - r(n, \lambda, I)$. This gain from contracting is also known as quasi-rent. Accordingly, the bargaining compensation for the grower is expressed as:

$$p^* = r(n, \lambda, I) + \alpha[b(I) - r(n, \lambda, I)], \text{ where } \alpha \in [0,1].$$

Vukina and Leegomonchai (2006) assumed that α is equal to one-half for simplicity, which we follow as well and obtain the first-order condition with respect to investment as

$$\frac{1}{2}\left[\frac{\partial b(I)}{\partial I} + \lambda(1 - \frac{1}{n})\right] - c = 0.$$

It is straightforward from Equation (3) to determine that the optimal investment level occurs at $\frac{\partial b(I)}{\partial I} = c + [c - \lambda\left(1 - \frac{1}{n}\right)]$. Because the term in brackets is positive for meaningful cost value (Vukina and Leegomonchai, 2006, p. 594), it can be concluded that $\frac{\partial b(I)}{\partial I} > c$ (reflected as a steeper slope in the benefit function). The optimal investment in the presence of hold-up (denoted as I*_*under* in Figure 1) occurs to the left of the optimal investment level in the absence of hold-up. Thus, hold-up leads to underinvestment.

The model is extended to allow for a contract period. First, assume that the asset's useful life is T years, which depreciates equally over its lifetime. Once a contract period T_1 is negotiated, the salvage value and total bargaining compensation become

$$r(n, \lambda, I) = \frac{T - T_1}{T}\lambda I(1 - \frac{1}{n}),$$

$$p^* = \frac{T_1}{T}b(I) + r(n, \lambda, I, T_1) + \frac{1}{2}\left[\frac{T - T_1}{T}b(I) - r(n, \lambda, I, T_1)\right] = \frac{T + T_1}{2T}b(I) + \frac{T - T_1}{2T}\lambda I(1 - \frac{1}{n}).$$

Equation (4) shows that the salvage value r is a function of the contract period T_1. As the contract period increased, salvage value decreased. At one extreme, if the contract period equals the asset life, no salvage value remains when the contract period ends. Such a mechanism is captured by the introduction of the term $\frac{T - T_1}{T}$ in the expression for the salvage value.

Equation (5) provides a further analysis. It illustrates the mechanism by which the contract period functions and has three components: realized gain $\frac{T_1}{T}b(I)$ (increasing with contract period (T_1)), salvage value (decreasing with contract period), and half of the gain from contracting. Because investment benefits always outweigh the salvage value, the last term also decreases with the contract period. Therefore, these three components form two opposing forces. Specifically, when the contract period increases, a larger proportion of the investment benefit is realized, as reflected by the middle term $\frac{T_1}{T}b(I)$. As a result, the grower has a smaller salvage value and the parties bargain over smaller proceeds (the term in the brackets of Equation (5)).[4] For example, when $T_1 = 0$, the equation reduces to Equation (2), which is the case addressed by Vukina and Leegomonchai (2006). When $T_1 = T$, the equation becomes $b(I)$ because the grower retains the full benefits of the investment, and thus there are zero proceeds left for bargaining. Intuitively, we would expect the positive impact of the contact period on the realized gain to dominate the other two effects. Therefore, we use comparative statics to signify the net effect of the contract period on optimal investment.

The new first-order condition becomes:

$$\frac{T+T_1}{2}\frac{\partial b(I)}{\partial I} + \frac{T-T_1}{2T}\lambda(1-\frac{1}{n}) - c = 0.$$

The comparative statics results derived from Equation (6) yield

$$\frac{\partial I^*}{\partial T_1} = \frac{-2T[c-\lambda\left(1-\frac{1}{n}\right)]}{\frac{\partial^2 b(I)}{\partial I^2}(T+T_1)^2} > 0.$$

$$\frac{\partial I^*}{\partial n} = \frac{-\lambda(T-T_1)}{\frac{\partial^2 b(I)}{\partial I^2}n^2 T(T+T_1)} \geq 0$$

This leads to the following main proposition:

Proposition 1: *The size of the grower's investment is positively related to the contract period.*

Equation (7) expresses Proposition 1: As illustrated in Figure 1, a longer contract period is hypothesized to shift the underinvested amount toward the optimal investment level in the absence of a hold-up.

[4] We thank the reviewers of this journal for suggestions on how to make this mechanism more realistic.

Proposition 2 follows equation (8) directly:

Proposition 2: *The size of the grower's investment does not decrease with the number of nearby integrators.*

Proposition 2 states that the number of buyers improves the underinvestment problem. We take both propositions into the data for the empirical testing.

Survey data on broiler growers

During the last 40 years, the broiler industry has become a pillar industry in many places in China because raising chickens can greatly promote farmer income by diversifying income sources. Chicken meat production in China was estimated to reach 15.8 million metric tons by 2020 (USDA, 2019). The main broiler species are white-feathered and yellow-feathered chickens, with the former being supplied to fast-food restaurants and the latter being supplied to traditional wet markets and supermarkets (Gong, 2016). As a Chinese domestic species, yellow-feathered chickens are considered high-quality local breeds with a better taste. Because of their low profit margin, most white-feathered chickens are produced based on large-scale breeding. In contrast, yellowed-feathered chickens are always raised by contracting with growers, partly because of the longer growing period associated with the species.

Jiangsu Province is the largest producer of yellow-feathered chickens. For this investigation, data from a survey of broiler growers raising yellow-feathered chickens in the province were used. The survey was conducted in 2015 by a group of researchers (professors and students) from the College of Economics and Management at a local university.[5] There are 13 prefecture-level city district areas in Jiangsu Province, indicated on the regional map in Figure 2. Focusing on 11 districts (excluding Nanjing City and Wuxi City), researchers randomly selected 35 large-scale broiler growers in each district for in-person interviews and 355 of the 395 questionnaires were validated and collected. The survey data contained information on farm location, socioeconomic characteristics of household heads, personal assets, investments in broiler operations (number, dollar value, size, and age of chicken

[5] The researchers spent about 1–2 hours collecting information from the head of household for each survey. They paid each grower 20 yuan as compensation for their time. A small subset of growers who rented chicken houses were excluded because they were unlikely to suffer from the hold-up problem.

houses), contract information (especially the contract period), subsidies received from integrator(s) and government, proportion of sales made through cooperatives, and risk aversion measures.

This study utilized only a portion of the variables available from the survey data. Table 1 presents the summary statistics for the variables used. The typical contracting broiler grower was mostly male, 49 years old, with a middle school education, and with seven years of experience as a broiler grower. For 96% of growers, the broiler business accounted for more than half of their gross farm income (data available in the survey but omitted from the table to conserve space). Similar to their U.S. counterparts, contract growers' indebtedness was significant in that 33% of the growers had broiler-related debt for raising chickens or building chicken houses, and 17% of the growers had broiler-related debt that exceeded ¥650,000 ($100,000) at the end of 2015.

On average, each grower had 1.4 chicken houses, with 32.8% having two or more. The size of the chicken houses ranged from 100,000–120,000 m^2. Approximately 2.76% of the growers claimed to have lost money in 2015, and 93% of the growers made a profit exceeding ¥20,000. The average period for raising chickens was 73 days.

Table 1 shows that the average investment in chicken houses totaled ¥2.18 million (all monetary variables here are expressed in 2015 yuan). This covers the accumulated investment spent on chicken houses dating back to as early as 1978, adjusted for inflation. The data show that the average contract period was 22 months, and the longest contract period was 12 years.

The table also lists the following variables, which are utilized in the empirical model discussed in the next section. Two measures were used for subsidies. *Integrator subsidy* is the subsidy amount received from the contracting integrator to build chicken houses, and *government subsidy* indicates whether government subsidies were received for raising chickens (yes = 1). *Cooperative sales* reflect the proportion of sales made through cooperatives. On average, this proportion was very small. *Technical guidance* indicates the number of times technical guidance was received from a contracting integrator per month. *Distance to the market* is the distance between the farm and the nearest free agricultural market. *Risk aversion* is the Arrow-Pratt measure of relative risk aversion (RRA). Following Tanaka et al. (2010) and Mao et al. (2019), we used economic experiments to elicit growers' risk preferences. Mao designed three series of lucky-draw games. Specifically, growers were invited to participate in the lucky draw three times. Each time, the game included 14 multiple-choice questions with two lucky-draw options. Option A was a lottery with a lower risk and a constant amount of bonus. Option B was a lottery with a higher risk and a gradually increasing amount of bonus. At the beginning of the lucky draw game, the growers tended to choose option A because option B was not attractive enough. However, the growers might change their choice from A to B when the bonus from option B increased to a certain point (from ¥34 to ¥850). The same method was used to obtain the risk-aversion measure. A higher risk-aversion coefficient indicates a higher degree of risk aversion. The full details are reported in Appendix A.

Using the grower locations reported in the survey, growers are plotted on a provincial map, as shown by the blue dots in Figure 2, using geographic information system (GIS) software. Integrators in the same province are plotted using red dots. In 2015, there were 165 integrators in the Jiangsu Province. The two largest integrators were Jiangsu Lihua Animal Husbandry Co., Ltd. (hereafter, Lihua) and Wen's Group. Vukina and Leegomonchai (2006) classified integrators' market power as monopsony, duopsony, oligopsony, or otherwise, because the U.S. integrator market was fairly concentrated at that time (about 2.5 integrators in a given area near a grower). In the present study, the map clearly indicates that the integrator market could be more competitive than the U.S. market, as characterized by the existence of hundreds of integrators within Jiangsu Province. Accordingly, the actual number of integrators in a given area around a grower is used to measure buyers' market power with better accuracy.

Ideally, to capture the degree of competition for the integrators, we would need to know the maximum distance that a farm can be located away from the processing plant and/or feed mill to be eligible to obtain a contract and then use this radius to count the number of integrators in that circle. However, the contracts we observed in Jiangsu Province did not specify this maximum distance. Alternatively, grower–integrator pair information in the data is used in a manner similar to that of Bar and Zheng (2019), who studied producers' choice of food safety certifiers based on producer–certifier pair information. Based on the grower–integrator pair information in the data, the furthest distance from a grower to the grower's chosen integrator was 67.1 km. In addition, at least one integrator can be found within a 47.1 km radius of a grower. Therefore, a radius of 57.1 km (the approximate midpoint between the two distances) is used here to define the market size of integrators in the model's base specification. Then, we vary the radius between 47.1 km and 67.1 km in increments of 5 km in the robustness check analysis. Based on a radius of 57.1 km, the minimum, average, and maximum numbers of integrators within this radius of a grower were 5, 14.75, and 30, respectively.

In Table 2, we present the detailed frequency distribution for the number of growers, by the number of integrators within our selected radius (57.1 km) near a grower and by the contract period. Table 2 (a) shows that 45.3% of growers had 5–10 integrators within this circle, and 36.3% of growers had 11–20 integrators within this circle. Therefore, unlike Vukina and Leegomonchai's (2006) study, in which the source of variation comes from monopsony to duopsony, oligopsony, and perfect competition, our variation comes from a somewhat competitive market to perfect competition. Our use of a smaller radius in the robustness check will provide insights into whether the results are robust when the competition measure is closer to Vukina and Leegomonchai's (2006) measure. Table 2 (b) shows that 65.9%, 21.4%, and 12.7% of the growers signed a contract with a period of less than one year, one to three years, and longer than three years, respectively, which means short-term contracts were the predominant format.

Empirical model

Based on the cross-sectional survey data, the following econometric model is proposed for growers' investment in chicken houses:

$$I_i = \beta_0 + \beta_1 Buyers_i + \beta_2 ContractPeriod_i + \beta_3 \boldsymbol{Subsidy_i} + \beta_4 Coop_i + \beta_5 Guidance_i + \beta_6 Distance_i + \beta_7 \boldsymbol{Demog_i} + \epsilon_i,$$

where subscript *i* indexes growers; I_i is the accumulated investment in chicken houses; $Buyers_i$ is the number of integrators offering contracts within a radius of 57.1 km around a grower; $ContractPeriod_i$ is the contract period between the grower and chosen integrator; $\boldsymbol{Subsidy_i}$ is a vector of subsidies consisting of the integrator subsidy amount to support building chicken houses, and the government subsidy dummy variable; $Coop_i$, $Guidance_i$, and $Distance_i$ represent the proportion of sales through the cooperative channel, the number of technical guidance received from the integrator per month, and the distance to the nearest agricultural market, respectively, in keeping with previous definitions; $\boldsymbol{Demog_i}$ is a vector of socioeconomic characteristics and the Arrow-Pratt risk aversion measure; and ϵ_i is the grower's idiosyncratic investment shock.

Because the integrator market power is measured here by the number count, it is implicitly assumed that the marginal impact of each integrator is equal. It is reasonable to expect that integrators will have heterogeneous impacts on growers, which could vary by integrator size. In reality, they have the potential to sell to the top integrators, which is likely to boost growers' investment by a larger degree. To further investigate the impacts of large versus small buyers, a variant of the base specification was estimated in the following form:

$$I_i = \beta_0 + \beta_1 Top2Buyers_i + \beta_2 SmallBuyers_i + \beta_3 ContractPeriod_i + \boldsymbol{\beta_4 Subsidy_i} + \beta_5 Coop_i + \beta_6 Guidance_i + \beta_7 Distance_i + \boldsymbol{\beta_8 Demog_i} + \epsilon_i,$$

where $Top2Buyers_i$ is the number of the top two integrators (Lihua and Wen's) within a given radius around a grower ($Top2Buyers_i = 0, 1, \text{or } 2$), and $SmallBuyers_i$ is the number of integrators other than the top two within a given radius around a grower. It is hypothesized that $\beta_1 > \beta_2$, given the previous discussion.

Estimation results

The model was estimated with Stata 16 using the ordinary least squares (OLS) method. The linear functional form was chosen to make the results comparable to those obtained by Vukina and Leegomonchai (2006). In addition, the errors were normally distributed. Owing to the use of cross-sectional data, robust standard errors were used in all specifications to correct for heteroscedasticity, as suggested by White's test. Table 3 presents the regression results. Specification (1) includes core economic variables and excludes demographic variables. Specification (2) includes all the variables specified in Equation (9). We focused on interpreting the coefficients using this specification. In a cross-sectional study, R^2 was reasonably high (0.235).

The results indicate that for each additional integrator near the grower, the grower's investment increased by ¥123,000, which was approximately 5.65% of the average grower's investment in chicken houses (based on the summary statistics in Table 1). This result, which was statistically significant at the 1% level, provides strong evidence for the existence of the hold-up problem in China's broiler industry, and thus for Proposition 2. This result also echoes Vukina and Leegomonchai's (2006) findings for the United States. They found that the average grower investment under monopsony was 0.54, less than that under a competitive market. This amounts to an almost 20% decrease, considering that the average starting number of houses per farm was 2.7. Based on the results of this study, reducing the average number of integrators near a grower from 14.75 to monopsony would reduce grower investment by 78%. The impact of buyers on grower investment seems to be larger in the present study.

Surprisingly, no evidence was found indicating a relationship between the contract period and the grower's investment (Proposition 1). The estimated parameter for the contract period was not statistically significant (using 5% as the default level). As mentioned in

Section 2, one possible explanation is that the integrator does not guarantee the minimum purchase of flocks in a typical contract. This is also the case for the U.S. broiler industry.

Regarding subsidies, both integrator and government subsidies had a positive impact on growers' chicken house investments. In particular, a ¥1 increase in integrator subsidy resulted in a ¥5.687 increase in chicken house investment, acting like a multiplier (a finding statistically significant at the 10% level). In contrast, no statistically significant impact was found for sales through cooperatives, technical guidance, distance to market, or risk aversion measures. In terms of demographic variables, education had a positive impact on investment, whereas increased age had the opposite effect.

Specification (3) investigates whether subsidies or market channels could affect the hold-up problem by adding three separate interactions between the number of integrators and integrator subsidies, government subsidies, and cooperative sales. The results showed that an integrator subsidy moderated the hold-up problem somewhat, which was consistent with expectations (because integrators covered part of the chicken house investment). However, when other interactions were added, the base effects of government subsidy and cooperative sales became negative; therefore, the results for specification (2) were the main focus.

Based on specification (2), we divide the number of integrators into the top two integrators and the remaining small integrators, yielding the model specified in Equation (10). The results are reported in Column (4) of Table 3. Both measures of buyer counts were statistically significant at the 10% level or better, whereas the estimated coefficient for the number of top two integrators was more than nine times of the number of remaining small integrators (1,178 versus 128.3). These results reveal the large impact of the presence of leading buyers on growers' investment levels.

Complementary analyses

This subsection reports the results of several complementary analyses, largely serving as robustness checks. All analyses were based on the preferred specification, specification (2) in Table 3, which includes demographic variables. The first analysis examined the robustness of the results for varying the radius of the market around a grower from 47.1 to 67.1 km in 5-km increments. The results in panel (a) of Table 4 show that the coefficient for the number of buyers remained very robust (all statistically significant with varying magnitudes) across all radii.

The second analysis investigated the impact of the contract period on grower size. Using the growers' investment in chicken houses (dependent variable), we divided growers into three quantiles. Panel (b) of Table 4 shows the regression results for these variables. According to this subsample analysis, the impact of both buyers and contract periods tended to occur for mid-sized growers; the coefficients for both buyers and contract period were positive and statistically significant at the 5% level or better.

The third analysis addresses the concern of potential endogeneity with the number of integrators. For example, endogeneity could arise if unobserved factors are correlated with chicken house investments and integrators' location choice. To alleviate this concern, instrumental variable (IV) regression was performed. However, finding good instruments for this scenario is challenging because in many cases, factors such as labor and electricity costs could affect both integrators and growers, and IV regression results should be interpreted with this caveat in mind. Therefore, population density and the proportion of budget spent on energy saving and environmental protection for the city where a grower was located were selected as instruments. The intuition is that population density and the degree of a city's efforts to save energy and protect the environment (two macro-level variables) should affect an integrator's location choice but are much less likely to influence growers' chicken house investment level once they are already in that city.

In the first-stage regression, both instruments were positive and statistically significant, showing that integrators tended to be located in markets with a denser population or made greater efforts to save energy and protect the environment. The *F*-statistic in the first stage was 37.5, suggesting that these two instruments were strong instruments. The two-stage least squares (2SLS) results in panel (c) of Table 4 show that the number of buyers remained statistically significant and of a larger magnitude.[6]

The fourth analysis served as a placebo. Compared with chicken houses, broiler equipment such as wet curtain fans and automatic spray equipment are less specific because they are variable assets that can be easily sold within the breeding industry. Therefore, the preferred model was re-estimated by replacing the dependent variable with the number of broiler equipment invested in by a grower. It was expected that the link between the number

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[6] Alternatively, gross domestic product (GDP) was selected for the city where a grower was located. In the Jiangsu Province, areas with higher GDP are rich in high-tech, high value-added industries. Integrators tended to locate in areas that relied on agriculture and had lower GDPs. However, the macro-level city GDP should have little impact on growers' chicken house investment level. The results remained robust. The estimated coefficient for the number of buyers was 424.30, which is statistically significant at the 1% level.

of buyers and broiler equipment investment would be weaker due to weaker asset specificity. The data contained only 178 growers who recorded the quantity of broiler equipment invested, resulting in a smaller subsample. Panel (d) of Table 4 presents the results with this subsample. The number of integrators was not found to be statistically significant. This result lends support to our argument that hold-up problems tend to occur in assets with a high degree of specificity.

Finally, we address the limitation of the use of accumulated investment, dating back to as early as 1978. This is likely an innocuous measure for relatively new farmers in 2015 but not for long-time industry operators. To align the time frame of the dependent variables better than that of the independent variables, we use the accumulated investment dating back to 2012 and 2010, respectively. For these three- and five-year-long time windows, 75% and 53% of the cumulative investment in the data are zero, respectively, prompting us to use the Tobit model. The Tobit results in columns (1) and (2) of Table 5 still show a positive and statistically significant impact on the number of buyers and a statistically insignificant impact for the contract period. In the last two columns, we present the analysis in which we use the current-year investment for 2015 as the dependent variable. We report the results using the Tobit model (where only 88 out of the 355 households invested in 2015) and the results using OLS for households with a positive investment in 2015. The impact of the number of buyers remains positive and statistically significant for the OLS model, but not the Tobit model, which is consistent with our theoretical prediction that buyers increase *their investment level*.

Conclusions

As empirical evidence of the hold-up problem is very limited in the literature, this study focused on China's broiler industry and investigated the roles that buyers, marketing channels, and the government play in growers' optimal investment. In the proposed model, buyers (integrators) were allowed to affect growers' chicken house investment through their location near growers, contract period, and subsidy to build chicken houses. We utilized survey data on 355 growers from Jiangsu Province in 2015. Several findings emerged, along with policy implications. First, growers' chicken house investments (assets with a high degree of physical and location specificity) increased with the number of potential buyers nearby. When broken down into the top two integrators versus the remaining smaller integrators, it was found that the impact of a top-two integrator nearby increased growers' investment by nine times that of a smaller integrator, highlighting the large impact of leading buyers nearby. These results demonstrate the existence of hold-up in China's broiler industry and echo previous findings for the U.S. broiler industry, which has a similar contract farming business model.

Second, in contradiction to the theoretical prediction, no evidence of a positive relationship between contract period and growers' investment was found. When the contract effect was allowed to vary by grower size, the subsample analysis indicated that the contract period increased the investment level for mid-sized growers only. Overall, the results offer weak evidence of the role of the contract period. One likely reason is that a typical contract does not guarantee the minimum number of flocks an integrator is obliged to purchase annually, reducing the material benefits of a long-term contract.

Hold-ups are known to lead to underinvestment problems. The key policy implications of this study are the identification of potential ways to alleviate the underinvestment problem. Subsidies received from a buyer or government could stimulate broiler growers' investments in chicken houses. Therefore, from the government perspective, providing subsidies can encourage further private investment, alleviating the underinvestment caused by the hold-up problem. From the buyer's perspective, providing subsidies to growers will likely provide assurance regarding the benefits of investing in chicken houses and, therefore, will lead growers to carrying out more upgrades.

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TABLE 1 Summary statistics of the variables used in this study

Variable	Definition	Mean	SD	Min.	Max.
House investment	Accumulated investment in chicken houses (thousand yuan)	2,177.96	6,614.94	21.90	72,000
Equipment investment	Number of broiler equipment units owned by growers	3.65	4.66	0	40
Number of buyers	Number of integrators offering contracts within a radius of 57.1 km	14.75	7.35	5	30
Contract period	Contract period (months)	21.55	37.33	0	144
Integrator subsidy	Subsidy from integrators for building chicken houses (thousand yuan)	152.57	426.59	0	5,905.92
Government subsidy	Government subsidies received for raising chickens (0 = no; 1 = yes)	0.12	0.33	0	1
Cooperative sales	Proportion of sales through cooperative(s)	2.20	14.66	0	100
Technical guidance	Technical guidance received from integrators (number per month)	8.52	5.78	0	30
Distance to market	Distance to the closest free agricultural market (km)	6.17	9.37	0.25	115
Risk aversion	Arrow-Pratt measure of RRA	0.63	0.46	0.05	1.50
Experience	Years of experience farming chickens	7.19	5.33	0	34
Gender	Gender (1 = male; 0 = female)	0.83	0.37	0	1
Age	Age (years)	48.88	9.54	26	73
Education	Education (years)	7.51	2.73	0	15

RRA = relative risk aversion.

Source: Broiler growers' survey in Jiangsu Province, 2015 (sample size = 355). Household socioeconomic characteristics were recorded for the household head. Sample size is 355.

TABLE 2 Frequency distribution of growers

a. By the number of integrators near a grower within our selected radius (57.1 km)

Number of integrators	Grower frequency	Percent	Cumulative frequency
5~10	161	45.35	45.35
11~20	129	36.34	81.69
21~30	39	10.99	92.68
31~35	26	7.32	100.00
Total	355	100	

b. By the contract period between a grower and integrator

Contract period	Grower frequency	Percent	Cumulative frequency
Less than one year	234	65.92	65.92
One to three years	76	21.41	87.32
More than three years	45	12.68	100
Total	355	100	

TABLE 3 Estimation results for chicken house investments

Independent variables	(1) Core variables	(2) With demographi	(3) With interactions	(4) Top-two buyers
Number of buyers	117.100***	123.000***	182.700***	
	(41.760)	(41.940)	(46.400)	
Contract period	-8.962	-9.058	0.463	-6.673
	(5.740)	(5.846)	(5.299)	(5.939)
Integrator subsidy	5.758*	5.687*	19.390***	5.593*
	(2.993)	(2.989)	(3.609)	(3.086)
Government subsidy	4,021**	3,641**	-4,037**	3,677**
	(1,795)	(1,696)	(1,857)	(1,686)
Cooperative sales	65.510	59.750	-137.900	57.740
	(84.990)	(85.130)	(120.100)	(83.940)
Technical guidance	-92.680	-40.450	-77.060	-32.050
	(65.330)	(63.760)	(54.940)	(64.380)

Distance to market	-10.870 (23.000)	-10.030 (22.040)	-6.891 (19.710)	-16.180 (23.980)
Risk aversion		495.600 (509.200)	-177.800 (505.600)	588.200 (506.700)
Experience		121.100 (81.330)	95.880 (72.580)	116.600 (78.080)
Gender		629.400 (554.800)	555.700 (604.200)	595.500 (560.300)
Age		-63.290* (32.270)	-30.460 (24.440)	-58.240* (31.520)
Education		291.600* (152.600)	276.900* (142.900)	308.300** (155.200)
Buyer × integrator subsidy			-1.058*** (0.273)	
Buyer × government subsidy			531.100** (208.200)	
Buyer × cooperative sales			15.420 (13.300)	
Number of top-two buyers				1,178.000* (659.300)
Number of small buyers				128.300*** (43.920)
R^2	0.235	0.235	0.268	0.278

Note: The sample size is 355 for all; robust standard errors are in parentheses. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE 4 Complementary analyses

a. Results of varying radius

Independent variables	(1) d = 47.1	(2) d = 52.1	(3) d = 57.1	(4) d = 62.1	(5) d = 67.1
Number of buyers	89.580***	114.000***	123.000***	139.200***	122.600***
	(33.260)	(39.900)	(41.940)	(42.210)	(40.670)

b. Impact of contract period by grower size

Independent variables	(1) Smallest growers	(2) Mid-size growers	(2) Largest growers
Number of buyers	-17.200	8.141**	238.000
	(21.670)	(3.444)	(146.700)
Contract period	3.229	5.230***	-5.988
	(7.873)	(1.452)	(16.440)

c. 2SLS estimation

Independent variables	With IVs
Number of buyers	679.500***
	(206.800)
Contract period	-12.520
	(7.698)

d. Buyer impact on broiler equipment

Independent variables	With different investment
Number of buyers	0.077
	(0.049)

Note: The sample size is 355 for (a), (b), and (c), and 178 for (d); robust standard errors are in parentheses. ***p < 0.01; **p < 0.05; *p <0.1.

TABLE 5 Analyses using different investment periods

Independent Variables	Cumulative Investment		Investment for Year 2015	
	(1) Tobit 5 Years	(2) Tobit 3 Years	(3) Tobit	(4) OLS for positive investment
Number of buyers	258.2***	118.1**	0.379	0.801**
	(66.32)	(52.56)	(0.284)	(0.350)
Contract period	1.786	8.033	0.0632	0.0207
	(12.91)	(9.280)	(0.0454)	(0.0451)

Note: The sample size is 355 for (1) – (3) and 88 for (4); robust standard errors are in parentheses. ***p < 0.01; **p < 0.05; *p < 0.1.

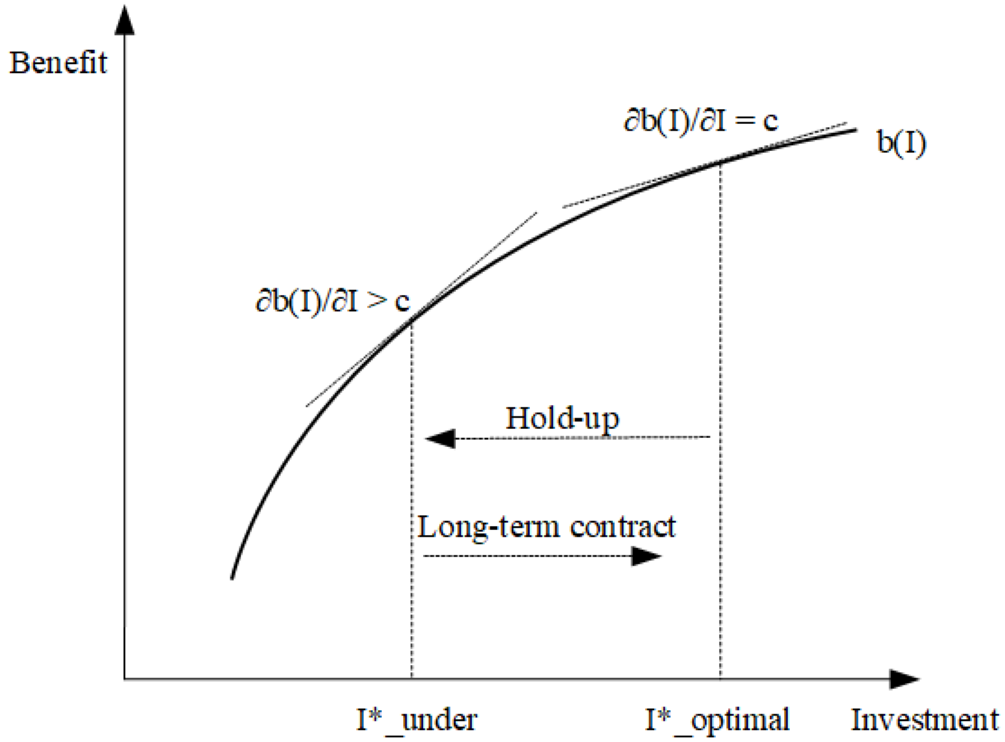

FIGURE 1 Impact of the hold-up problem on optimal investment

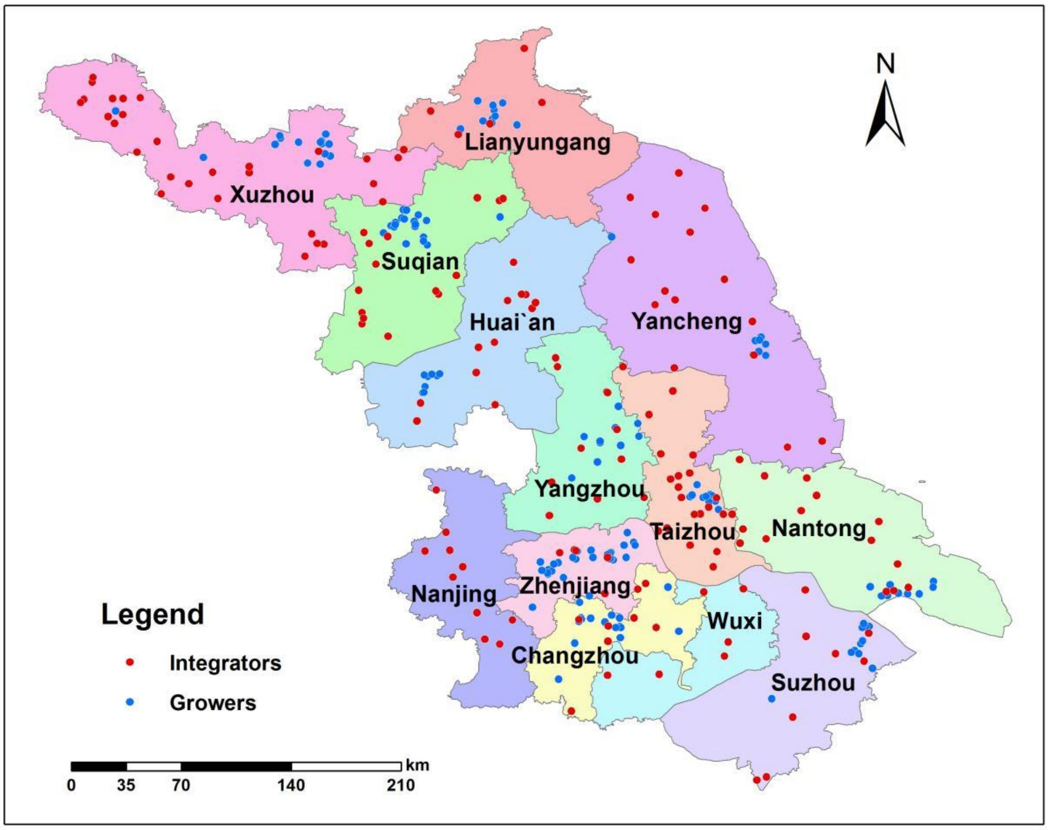

FIGURE 2 GIS map of broiler growers and integrators in Jiangsu Province, China, in 2015

APPENDIX A. Measuring Growers' Risk Preference

To measure the risk preference coefficient of growers, we designed three series of lucky draw games, as shown in Appendix Table 1. Game 1 includes 14 multiple-choice questions, and each question has two lucky draw options, A and B. Option A is a lottery with low risk, and the amount of bonus remains unchanged; Option B is a high-risk lottery, and the bonus increases gradually. For example, in the first question of lottery game 1 in Table 1, option A has a 30% chance to get 20 yuan and 70% chance to get 5 yuan; Option B has a 10% chance to get 34 yuan and a 90% chance to get 2.5 yuan. At the beginning of the lucky draw games, the growers may choose option A because B is not attractive enough. However, with the increasing bonus of option B (from 34 yuan to 850 yuan), growers will have more incentive to take risks. Finally, the growers' choices will turn from A to B at a certain point. Subsequently, we set up different bonuses of game 2 and game 3 to make a comparison. When the growers finish all the lucky draw games, the growers randomly draw a card in the black bag and use the real money for the lucky draw game to ensure that the growers' answers in the games are rational.

According to the conversion point of the growers in the lottery games, we obtain the coefficient of risk aversion σ for each grower. Suppose that in game 1 and 2, a grower turns to choose options A to B in line 7, the following inequalities should be satisfied:

$$5^{1-\sigma}+\exp[-(-\ln 0.3)^{\alpha}](20^{1-\sigma}-5^{1-\sigma})>2.5^{1-\sigma}+\exp[-(-\ln 0.1)^{\alpha}](62.5^{1-\sigma}-2.5^{1-\sigma})\,(\mathrm{I})$$

$$5^{1-\sigma}+\exp[-(-\ln 0.3)^{\alpha}](20^{1-\sigma}-5^{1-\sigma})<2.5^{1-\sigma}+\exp[-(-\ln 0.1)^{\alpha}](75^{1-\sigma}-2.5^{1-\sigma})\quad(\mathrm{II})$$

$$15^{1-\sigma}+\exp[-(-\ln 0.3)^{\alpha}](20^{1-\sigma}-15^{1-\sigma})>2.5^{1-\sigma}+\exp[-(-\ln 0.7)^{\alpha}](32.5^{1-\sigma}-2.5^{1-\sigma})\,(\mathrm{III})$$

$$15^{1-\sigma}+\exp[-(-\ln 0.3)^{\alpha}](20^{1-\sigma}-15^{1-\sigma})<2.5^{1-\sigma}+\exp[-(-\ln 0.7)^{\alpha}](34^{1-\sigma}-2.5^{1-\sigma})\,(\mathrm{IV})$$

The range of σ can be obtained by solving Eqs. (I) to (IV) (taking the midpoint of the range as the estimated value of risk aversion.

APPENDIX Table 1

Option A		Option B		Expected payoff difference (A–B)
Game 1				
Cards 1–3	Cards 4–10	Card 1	Cards 2–10	
20	5	34	2.5	3.85
20	5	37.5	2.5	3.50
20	5	41.5	2.5	3.00
20	5	46.5	2.5	2.60
20	5	53	2.5	1.95
20	5	62.5	2.5	1.00
20	5	75	2.5	-0.25
20	5	92.5	2.5	-2.00
20	5	110	2.5	-3.75
20	5	150	2.5	-7.75
20	5	200	2.5	-12.75
20	5	300	2.5	-22.75
20	5	500	2.5	-42.75
20	5	850	2.5	-77.75
Game 2				
Cards 1–9	Card 10	Cards 1–7	Cards 8–10	
20	15	27	2.5	-0.15
20	15	28	2.5	-0.85
20	15	29	2.5	-1.55
20	15	30	2.5	-2.25
20	15	31	2.5	-2.95
20	15	32.5	2.5	-4.00
20	15	34	2.5	-5.05
20	15	36	2.5	-6.45
20	15	38.5	2.5	-8.20
20	15	41.5	2.5	-10.30
20	15	45	2.5	-12.75
20	15	50	2.5	-16.25
20	15	55	2.5	-19.75
20	15	65	2.5	-26.50
Game 3				
Cards 1–5	Cards 6–10	Cards 1–5	Cards 6–10	
12.5	-2	15	3	3
2	-2	15	-2.25	-2.25
0.5	-2	15	-3	-3
0.5	-2	15	-4.25	-4.25
0.5	-4	15	-5.25	-5.25
0.5	-4	15	-5.75	-5.75
0.5	-4	15	-6.50	-6.50

(!!! INVALID CITATION !!!).

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