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Model of real estate regulation policy classification based on Michaelis-Menten equation

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ABSTRACT

Real estate is complex ecosystem with multiple factors related to human society. For a long time, real estate regulation policy in China focuses on statistics rather than classification analysis, less ecotype evaluation. Michaelis-Menten equation is a model used to descrbe enzyme kinetics by relating enzymatic reaction rate to the concentration of a substrate. It was used to analyze the real estate policy, control and regulation by simulation of inhibition mechanism, and classification of competitive, non-competitive, mixed and uncompetitive for distinction. This model would to be a new way and helpful to study policy ecologically of the real estate industry.

KEYWORDS

Real estate; Regulation policy; Ecotype evaluation; Michaelis-Menten equation; Classification.

INTRODUCTION

Real estate is property consisting of land and the buildings on it, along with its natural resources such as crops, minerals, or water; immovable property of this nature; an interest vested in this; also an item of real property; more generally buildings or housing in general, also the business of real estate; the profession of buying, selling, or renting land, buildings or housing[1]; meanwhile it is a complex ecosystem influenced by human beings. In countries with large population but relatively scare land, especially those in Asia, such as Japan, Singapore and China, Real estate regulation policy plays an important role in maintaining a sustainable real estate market and sustainable economic development.

For a long time, regulation model of real estate was studied from the perspective of economics, and policy was made according to the result of absolute numbers of trading volume, prices and rates statistics of growth or reduction. Optimization and analysis of capital operation was focused, in the field of land policy, monetary policy and tax policy evaluation, but few researches in objective law of other systems such as currency operation principle, consumers' psychological demands and ecosystem. Real estate regulation policy shall not be a problem of economics and management science only, but also of psychology, sociology and natural science, which is the broad ecological environment of real estate, so interdisciplinary methods and theories could be used to simulate and explore some potential laws.

MICHAELIS-MENTEN EQUATION

In biochemistry, it has been shown experimentally that if the amount of the enzyme is kept constant and the substrate concentration is then gradually increased, the reaction velocity will increase until it reaches a maximum. After this point, increases in substrate concentration will not increase the velocity. Enzyme kinetics curve is shown in Figure 1.

Michaelis–Menten kinetics equation is one of best-known models of enzyme kinetics, named after German biochemist Leonor Michaelis and Canadian physician Maud Menten. The model takes the form of an equation describing the rate of enzymatic reactions, by relating reaction rate v to [S], the concentration of a substrate S. Its formula is given by

$$v = \frac{V_{max} \cdot [S]}{K_m + [S]} \qquad \textbf{(1)}$$

Here, V_{max} represents the maximum rate achieved by the system, at maximum saturating substrate concentrations. The Michaelis constant K_m is the substrate concentration at which the reaction rate is half of V_{max}[2]. Biochemical reactions involving a single substrate are often assumed to follow Michaelis–Menten kinetics, without regard to the model's underlying assumptions.

In 1913, equilibrium-state model (shown in Figure 2) was elaborated by Michaelis and Menten, theorized that when this maximum velocity had been reached, the entire available enzyme had been converted to ES, the enzyme substrate complex. This point on the graph was designated V_{max}. It involved an enzyme (E) binding to a substrate (S) to form a complex ES, which in turn was converted into a product (P) and the enzyme, where k_f, k_r and k_{cat} denoted the rate constants and the double arrows between S and ES represented the fact that enzyme-substrate binding was a reversible process. Using this maximum velocity and equation Michaelis developed a set of mathematical expressions to calculate enzyme activity in terms of reaction speed from measurable laboratory data[3], and

$$K_m = (k_r + k_{cat}) / k_f \qquad \textbf{(2)}$$

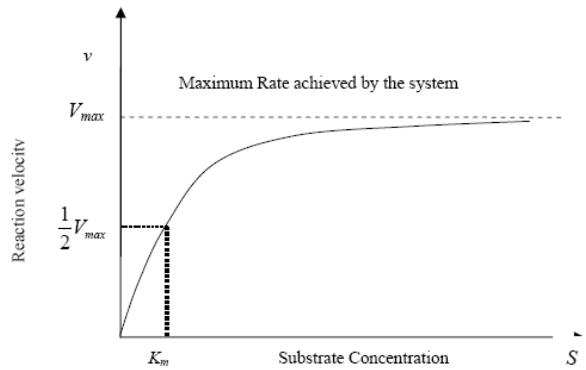

Figure 1 : Saturation curve for enzyme

$$E+S \underset{k_r}{\overset{k_f}{\rightleftharpoons}} ES \xrightarrow{k_{cat}} E+P$$

Figure 2 : Equilibrium-state model（single substrate）

Several assumptions were made for the model (apart from the general assumption about the mechanism only involving no intermediate or product inhibition, and there was no allostericity or cooperativity) [4] [5]:

①The concentration of the intermediate complex did not change on the time-scale of product formation – known as the quasi-steady-state assumption. There was only one kind of intermediate complex, and the first step of Figure 2 was reversible.

②The enzymatic mechanism for the unimolecular reaction（step 2）could be quite complex, but typically one rate-determining enzymatic step that allowed this reaction to be modeled as a single catalytic step with an apparent unimolecular rate constant k_{cat}. If the reaction path proceeded over one or several intermediates, k_{cat} would be a function of several elementary rate constants, whereas in the simplest case of a single elementary reaction it would be identical to the elementary unimolecular rate constant k_r, and the rate-determining enzymatic step was slow compared to substrate dissociation ($k_r >> k_{cat}$). It held if the enzyme concentration was much less than the substrate concentration.

③If $[S]$ was very small compared to K_m and then $[S]_0 >> [E]_0$ when started, and also very little ES complex was formed, thus $[E]_0 \approx [E]$, and $[S]_0 \approx [S]$.

④The total enzyme concentration did not change over time, E was a catalyst, which only facilitated the reaction, so that its total concentration, free plus combined, was shown as conservation equation of enzyme: $[E] + [ES] = [E]_0 = [E]_{total}$.

⑤The concentration of substrate was very much larger than the concentration of products:$[S] >> [P]$. This was true under standard in vitro assay conditions, and true for many in vivo biological reactions, particularly where the product was continually removed by a subsequent reaction in biology.

APPLICABILITY OF MICHAELIS-MENTEN EQUATION IN REAL ESTATE

Fund flow

The most intuitive and quantifiable index is capital in real estate regulation. Fund flow works as chemical reaction in ecological environment of human society and economic life, and it is easy for "chemical reaction" simulation or modeling with fund flow because capital in a regional or limited market is relatively single-resourced and illiquid.

For the real estate market, the total amount of funds controlled by consumers is very huge as any family and personal property is widely distributed in the immovable property, deposit, financial products, cash and securities, which is an important part of total economic aggregates especially based on a large population for a country or region. The total liquid funds disposed by developers in this market, without considering lending transaction, loan, capital financing and housing sales recycling, the quantity is much smaller and relatively low by several orders of magnitude.

Demand and need

Traditional regulation model of real estate emphasizes much on data statistics and the flow of funds above, but other factors and participants in the whole social and ecological environment are more difficult to quantify, especially specific quantization of the consumers' demand and psychological need, even derived from the total population. Model of chemical reaction will be effective to explain this kind of abstract demand-driven quantification.

For the real estate market, demand and need of consumers is huge because of population density and mobility, including rigid demand for marriage or work, improving living conditions, business expansion or relocation and investment. However, as to a limited spatial or specific regional market, such as for a city or town, the demand is relatively small, leading to that unsatisfied need and demand is limited but still bigger than the amount of houses provided by developers, because regulation will be of no significance when the supply exceeds the demand. In this model, the result of the chemical reaction shall be housing transactions, which is the satisfied demand, instead of housing stock[6].

MODEL OF REAL ESTATE REGULATION

Based on Michaelis-Menten Equation and applicability above, Model of Real Estate Regulation (MRER) is established, and its process shown as Figure 3:

$$E+S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_3} E+P$$

Figure 3 : Model of Real Estate Regulation

Substrate S represents disposable money owned by consumers demanding houses and their unsatisfied needs;

Enzyme E represents money owned by developers and tradable houses inventory;

Product P represents fund flow when housing transaction is finished and satisfied needs;

Intermediate ES represents fund flow in transaction process including advanced deposit, mortgage loan, financing and process when seeking house resources to satisfy needs;

V_{max} means velocity to finish the process, which can be described by the time scale or time span. Velocity in actual life can be used to evaluate prosperity of a property market, intuitively consumers' enthusiasms for transactions and wills to purchase houses.

This model uses equilibrium-state model to describe a process in real estate market, and Michaelis–Menten kinetics equation is valid, also similar assumption mentioned above as follows:

①The process of seeking houses and fund flow is object to single targeted house, because one consumer buy only one house in a hosing transaction, meet one need and price for it is specific, also its result of financing. That is single intermediate, although the course is complicated and dynamic game, the double arrows between S and ES represents the fact that it is a reversible process with bargains and communications between consumer and developer.

②Inventory consumption has little influence on fund flow and needs for houses. For following research of regulation, the targeted market shall be big enough with sufficient house in stock, and consumers can choose houses in different districts of the city or town with different characteristics, so $[S]$ big enough while regulation is necessary. Money earned by selling house has little impact on fund flow for developers. Then regulation effectiveness can only be shown in housing transaction, and velocity controlled by slow step related to intermediate, getting that $v = k_3[ES]$.

③Demand and fund flow of total consumers in the market system are much bigger than houses in stock provided by developers and enterprises' own fund flow.

④Developers do not consume money in transaction. Fund low of them do not change before selling houses for no other financing methods; house inventory (needs to satisfy consumers) remains unchanged also when no deal is done, no house is sold.

⑤No considering that house sold returned to developers; Transaction finished when house was sold. Consumers can not ask their money back, they confirm the transactions. No regret and also no repurchase.

MODEL OF REGULATION CLASSIFICATION

Inhibition is usual in a process of control and always the result of mutual regulation of factors in an ecosystem. In the control process of ecosystem, due to the presence of a large number of dynamic equilibrium, excitations and inhabitations coexist and keep balance easily; in human society, economic activities also remain tensile, dynamic and flexible, inhibition contrast to motivation is then reversible and exchangeable as well. In real estate market, this control process is very common and complicatedly reversible for rigid demand, rational living demand and investment need, showing that capital is profit-driven. It needs to be pointed out that regulation does not always lead to inhibition, but in Michaelis–Menten kinetics enzyme inhibition is thoroughly studied, so the model establishes based on inhibition regulation; the critical point of research here is the classification of real estate regulation ecologically rather than inhibition result itself.

An enzyme inhibitor is a molecule that binds to enzymes and decreases their activity. Reversible inhibitors bind non-covalently and different types of inhibition are produced depending on whether these inhibitors bind to the enzyme, the enzyme-substrate complex, or both. In this model, four types of reversible inhibition are shown as follows : competitive, non-competitive, mixed and uncompetitive, similar to that in biochemistry[7], and Inhibitor (I) is used to describe the change and influence of fund flow and demand by regulation policy. Competitive inhibition means that policy affects developers, non-competitive means that policy affects developers and process of seeking house (transactions) with the same influence, mixed means that policy affects developers and transactions with different influence, and uncompetitive means that policy affects transactions only.

Competitive inhibition

Regulation policy (I) affects developers (E) by competing with consumers (S). Mechanism is shown in Figure 4, and K_i is used as an inhibition constant, then $K_i = k_{i1}/k_{i2}$. E_f represents remaining factors unregulated of developers, $[E] = [E_f] + [ES] + [EI]$. According to Eq. (1) and assumption②③, it got Eq. (3):

$$\frac{V_{max}}{v} = \frac{[E_f]+[ES]+[EI]}{[ES]} \quad \textbf{(3)}$$

$K_m = \frac{[E_f][S]}{[ES]}$ and $K_i = \frac{[E_f][I]}{[EI]}$, so $[E_f] = \frac{K_m[ES]}{[S]}$, $[EI] = \frac{[E_f][I]}{K_i}$, easily got $[EI] = \frac{K_m[I]}{K_i[S]}[ES]$,

then put $[E_f]$ $[EI]$ into Eq. (3), got that $\frac{V_{\max}}{v} = \frac{\frac{K_m[ES]}{[S]} + [\mathrm{ES}] + \frac{K_m[I]}{K_i[S]}[ES]}{[ES]}$, finally got that

$$v = \frac{V_{\max}[S]}{K_m(1+\frac{[I]}{K_i})+[S]}.$$

In Figure 5, it is clear that competitive inhibition increases K_m, but does not affect V_{max}, and in Lineweaver–Burk plots, K_m' increases with more inhibition I, which implies that regulation policy makes developers E and consumers S less affiliated. While policy affects only developers, enthusiasm or need of consumers keeps, so velocity to finish the process of transaction is the same.

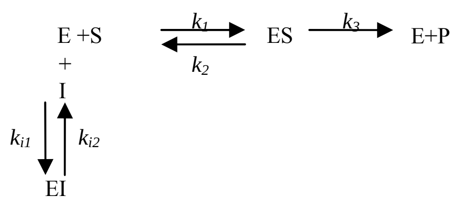

Figure 4 : Mechanism of Competitive inhibition

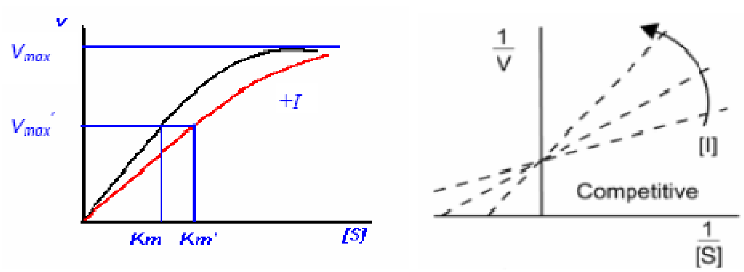

Figure 5 : Analysis of Competitive inhibition

Non-competitive inhibition

Regulation policy (I) affects developers (E) also transactions (ES), but does not affect consumers (S), which non-competitive means that inhibitors have identical affinities for E and ES, so policy have impact on developers and the trade process,(for instance, tax rate) but developers are still willing to bargain with consumers. As mechanism shown in Figure 6, new factor ESI shall be considered, and $[E] = [E_f] + [ES] + [EI] + [ESI]$. According to Eq. (1) and assumption②③ also, it got that

$$v = \frac{V_{max}[S]}{(K_m+[S])(1+\frac{[I]}{K_i})}.$$

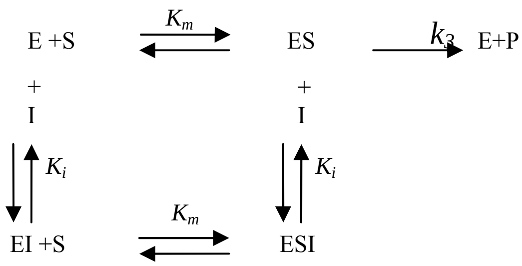

Figure 6 : Mechanism of Non-competitive inhibition

In Figure 7, the extent of inhibition V_{max}' depends only on the concentration of the inhibitor. V_{max} will decrease due to the inability for the reaction to proceed as efficiently, but K_m will remain the same. Regulation policy does not affect the affinity between developers and consumers, but it makes split-flow of developers' house inventory and fund flow (additional fees or tax), also of consumers' needs and money to purchase houses (more transaction tax), so the entire enthusiasms of the market decline.

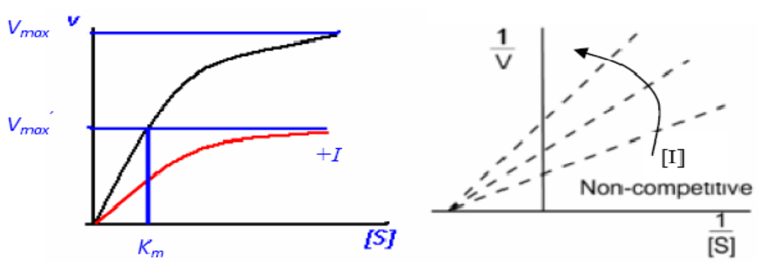

Figure 7 : Analysis of Non-competitive inhibition

Mixed inhibition

In mixed inhibition, which mixed means that inhibitors have different affinities for E and ES, so policy (I) can affect developers (E) at the same time as consumers (S), but consumers affects policy and vice versa, so it seems more close to actual society. In Figure 8, policy has different impact on developers and transactions (K_i and K_i'), so it got that

$$v = \frac{V_{max}[S]}{K_m(1+\frac{[I]}{K_i}) + [S](1+\frac{[I]}{K_i'})}.$$

In Figure 9, mixed-type inhibitors increase K_m and decrease V_{max}. Regulation policy affects developers and transactions in different ways, making a dynamic game theory. It is the situation in actual life: consumers buy houses with more enthusiasms after regulation, but transactions slow down.

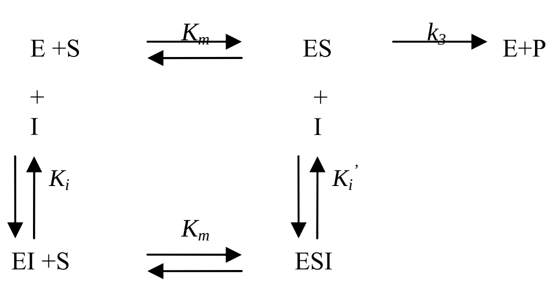

Figure 8 : Mechanism of mixed inhibition

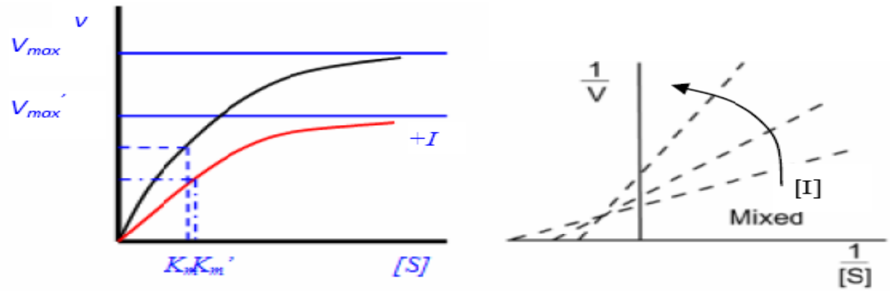

Figure 9 : Analysis of mixed inhibition

Uncompetitive inhibition

In uncompetitive inhibition, the inhibitor binds only to the substrate-enzyme complex, and inhibition causes V_{max} to decrease and K_m to decrease. Mechanism is shown in Figure 10, and it got that

$$t v = \frac{V_{max}[S]}{K_m + [S](1+\frac{[I]}{K_i})}.$$

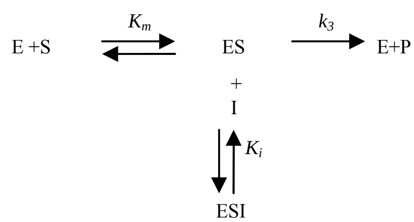

Figure 10 : Mechanism of uncompetitive inhibition

In uncompetitive inhibition, regulation policy affects consumers only, in the process of seeking houses and transactions. However, in a rational market it is rare that factors influence consumer only. Needs and demand regulated by government is impossible, or it shall result from consumers themselves (lack of money, better investment, changed will). This kind of regulation should be theoretical analysis only, but does not exist in reality.

CONCLUSIONS

The elaboration of MRER above analyzed the real estate regulation policy by simulation of inhibition mechanism, and classification of competitive, non-competitive, mixed and uncompetitive for distinction. By classification, different policies could be made for different developers and consumers, thus leading an ecological industry environment of diverse selection and sustainable real estate market.

Different people have different needs, attitudes and affinities to developers, so government should make policies for consumers of different social class with various demands and will to purchase houses and properties. MRER helps to distinguish market segments while to establish targeted regulation and control measures by analysis and evaluation of statistics (for example, time span) in transaction.

MRER provides a method of quantitative evaluation for those abstract and microcosmic factors. Instead of traditional Volume and Price calculation, it implies inner operation of fund flow and housing sales in a property developer with a definite mechanism rather a qualitative analysis or evaluation, and helps for further scientific and objective research.

Last but not the least, MRER may analyze the effectiveness of definite regulation policy. It is difficult to define whether policy affects consumers, developers, or both, but mechanisms above as competitive, non-competitive or mixed will be an innovation, maybe a linear equation could be built for quantitative correlation with comprehensive cases investigation or regional data.

ACKNOWLEDGEMENTS

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