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## Qualitative and quantitative combined nonlinear dynamics model and its application in analysis of price, supply–demand ratio and selling rate



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## ABSTRACT

The qualitative and quantitative combined nonlinear dynamics model proposed in this paper fill the gap in nonlinear dynamics model in terms of qualitative and quantitative combined methods, allowing the qualitative model and quantitative model to perfectly combine and overcome their weaknesses by learning from each other. These two types of models use their strengths to make up for the other's deficiencies. The qualitative and quantitative combined models can surmount the weakness that the qualitative model cannot be applied and verified in a quantitative manner, and the high costs and long time of multiple construction as well as verification of the quantitative model. The combined model is more practical and efficient, which is of great significance for nonlinear dynamics. The qualitative and quantitative combined modeling and model analytical method raised in this paper is not only applied to nonlinear dynamics, but can be adopted and drawn on in the modeling and model analysis of other fields. Additionally, the analytical method of qualitative and quantitative combined nonlinear dynamics model proposed in this paper can satisfactorily resolve the problems with the price system's existing nonlinear dynamics model analytical method. The three-dimensional dynamics model of price, supply–demand ratio and selling rate established in this paper make estimates about the best commodity prices using the model results, thereby providing a theoretical basis for the government's macro-control of price. Meanwhile, this model also offer theoretical guidance to how to enhance people's purchasing power and consumption levels through price regulation and hence to improve people's living standards.

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## 1. Introduction

The existing research in the qualitative and quantitative combined model is terribly rare. Such kind of model, represented by AHP (analytical hierarchy process), is a qualitative and quantitative combined evaluation model which can solve complex multiple-target problems. In AHP, the relative importance of each standard for “measuring if the goals can be achieved” is determined by the experience of decision-

makers, which is qualitative in the AHP model; then, the weight of each standard for each decision program will be reasonably given, and then is used to figure out the order of advantage and disadvantage of each program, which is quantitative in the AHP model. The quantitative data in AHP model are valuation data derived from qualitative judgment (i.e. quantitative data are used to describe the qualitative logical results, such as the description of the relationship using specific weights). But such valuation is made based on people's experience and knowledge, so it is inaccurate. Therefore, the “existing qualitative and quantitative combined model” represented by AHP model assists the qualitative research by quantitative means. The data for quantitative analysis are not

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objective and factual historical data and experimental data, but only quantitative valuation of qualitative results. The advantage of the quantitative model lies in its basis on the historical data and experimental data of objective facts (use of mathematical methods) and on facts, so the quantitative model is obviously more scientific than the qualitative one. The “existing qualitative and quantitative combined model” fails to use such advantage of the quantitative model, and only provides approach to the “quantitative analysis of qualitative problems”.

In addition to qualitative and quantitative combined model research represented by AHP, there are also some other studies on the qualitative and quantitative combined model. For instance, the existing quantitative model is extended to add a semantic layer [1] in order to receive qualitative knowledge, but the independent quantitative model and qualitative model are not combined. Besides, such an extended model can only be applied in stochastic simulation, but not in the field of nonlinear dynamics. Another two models combine qualitative and quantitative models with goal programming and AHP [2], but these two models only quantify the qualitative knowledge, rather than combine the independent quantitative model and qualitative model; besides, they can only be applied in the domain of linear programming, but not in that of nonlinear dynamics. Additionally, a model quantifies qualitative knowledge with signed direct graph (SDG) and fuzzy set theory [3], but fails to combine the independent quantitative model and qualitative model; and they only be applied in the domain of pattern recognition.

Also, another model quantifies qualitative description [4], rather than combine the independent quantitative model and qualitative model; they can only be applied in the domain of emotions, but not in the field of nonlinear dynamics.

The existing technology does not include any methods combining qualitative model and quantitative model based on the historical data and experimental data of objective facts. Therefore, the qualitative and quantitative combined nonlinear dynamics model proposed in this paper fills this gap, allowing the nonlinear dynamics qualitative model to combine with nonlinear dynamics quantitative model based on the historical data and experimental data of objective facts. This method can be applied to the combination of the qualitative model with the quantitative model based on the historical data and experimental data of objective facts in other fields.

The existing research into a system's nonlinear dynamics model either only focuses on the qualitative modeling of such system or only on the quantitative modeling of such system. If only qualitative modeling is conducted, then the modeling results cannot guarantee the usefulness of such model, since the qualitative results are only the general logical relationship without precise quantitative measurement criteria, and thus cannot be applied in a quantitative manner in reality. For instance, the result of the qualitative model is that the result of a certain object is the Boolean value 1, indicating the amount should be increased, but how much the amount should be increased cannot be demonstrated in such results. Yet, the experiments of increasing amount in reality must provide a specific increased digital value. As a result, the qualitative model cannot be quantitatively applied in reality. Accordingly, the qualitative model cannot be quantitatively verified in reality. The qualitative model can only be

established and verified based on people's experience and knowledge. However, such experience and knowledge are limited and subjective so that the accuracy and objectivity of the qualitative model cannot be objectively guaranteed and verified through the model itself. In respect of the “qualitative and quantitative combined model” provided in this paper, the quantitative model takes the results of qualitative model as the qualitative guidance, rendering the quantitative model based on the results of the qualitative model and constructing the quantitative model through quantifying qualitative properties and qualitative relationship of the research objects. And the range of quantitative variables in the model is consistent with the restrictions of qualitative attributes and qualitative relationship. Thereby the quantitative model is the refinement and quantification of the qualitative model. Since the quantitative model is qualitatively consistent with the qualitative model, then the qualitative model qualitatively consistent with such quantitative model must be correct if the quantitative model is correct. The quantitative model can be addressed with the historical data of objective facts, and verified through the experimental data of objective facts. Consequently, if the quantitative model is verified to be correct by the objective experimental data, then the qualitative model qualitatively consistent with such quantitative model must be correct; if wrong, it may also be wrong. When the quantitative model is verified wrong by the objective experimental data, then it is necessary to check whether such error will lead the variable range in the quantitative model to exceed the limitations of the qualitative attributes and qualitative relationship in the qualitative model. If not, then the qualitative model is correct; the error is in the design of variable equations in the quantitative model, and a new quantitative model needs to be built based on the qualitative model. If yes, then the qualitative model is wrong, a new quantitative model needs to be built and a quantitative model to be built based on such new qualitative model. Therefore, the “qualitative and quantitative combined model” stated in this paper surmounts the shortcoming that the qualitative model cannot be quantitatively applied and verified and can ensure the accuracy and objectivity of the qualitative model. If only quantitative modeling is carried out, then the modeling cost and time are too much. The quantitative model needs to use the historical data of objective facts to resolve models, while using the experimental data of objective facts to verify models. For example, the nonlinear dynamics model generally uses nonlinear differential equation for modeling, generally multidimensional nonlinear differential equations. Nevertheless, the computational complexity of resolving the multidimensional nonlinear differential equations is exceedingly great, and sometimes it also takes hours to solve and verify such equations even with supercomputers. Consequently, the cost and time of quantitative model modeling and verification are generally many times those of qualitative model. If only the quantitative model is used, once the quantitative model fails the verification in the experimental stage, then it needs to return to correct and re-examine the quantitative model. In this way, the accumulative cost and time are much more considerable, which is the insufficiency of only using the quantitative model. The “qualitative and quantitative combined model” stated in this paper takes the results of qualitative

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