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REVIEW

The Voice of Physics in Finance: A Glance on the Theoretical Application of Heat Equation to Stock Price Diffusions

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ABSTRACT

Stock price volatility is considered the main matter of concern within the investment grounds. However, the diffusivity of these prices should as well be considered. As such, proper modelling should be done for investors to stay healthy-informed. This paper suggest to model stock price diffusions using the heat equation from physics. We hypothetically state that, our model captures and model the diffusion bubbles of stock prices with a better precision of reality. We compared our model with the standard geometric Brownian motion model which is the wide commonly used stochastic differential equation in asset valuation. Interestingly, the models proved to agree as evidenced by a bijective relation between the volatility coefficients of the Brownian motion model and the diffusion coefficients of our heat diffusion model as well as the corresponding drift components. Consequently, a short proof for the martingale of our model is done which happen to hold.

1. Introduction

Quants and econophysicists have become more popular and recognizable since the 2008 economic meltdown. Their unwary contributions and dormant to finance and economics led to poor and bad behaviour of the used models. In his book^[1], discusses about models behaving badly in the financial world. He posits that, bad models and confusing illusion with reality can lead to devastations and disasters in the Wall Street trading tables. In 2008, most firms closed while others experienced negative growth. Only Renaissance technologies managed to survive better in Wall Street as a Hedge Fund (thumbs up for Jim Simons-the mathematician). Therefore, such economic devastating effects can affect life too. Of course, models of financial nature do work well in most instances

but its success is contingent upon no even economic operations. Such models are not good at capturing market complexities. This implies that, needs for super imposed models that capture and model such complexities with frequent and more accurate forecasts are really required, thus, the emergence, existence and relevancy of financial physics in finance. This not so long paper aims to provide some theoretically based applications of the Brownian motion heat equation to modelling stock price diffusions. We follow the theory of^[2] on Brownian motion and stochastic processes guiding the stock market operations. Today, the concept of Brownian motion has been recognized in various ways as:

A process with independent homogenous increments whose paths are continuous. 2. The continuous time process which is the limit of symmetric random walks and

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lastly 3. the Markov process whose forward Kolmogorov equation is the heat equation. This study will focus on the third view, where we try to model the Markovness of stock prices using the diffusion heat equation. It is considerably valuable to analyze the paths taken by asset prices within markets especially to dynamic investors. This is because assets like stocks are dynamic and their prices are dynamic, continuous and random too. We theoretically study the diffusions associated with stock prices using the heat equation. Since its inception by ^[3], the heat equation has been exposed to wide and vast applications in the physics field not certainly in finance. In physics, we see the heat equation applied by ^[4] who investigated the effect of internal fins on flow pattern, temperature distribution and heat transfer between concentric horizontal cylinders for different fin orientations and fin tip geometry for Rayleigh numbers ranging from 103 to 106. They employed the two fin orientations used by ^[5]. Some other work is found in ^[6-8]. In addition, ^[9] studies the effect of magnetic field on the coupled heat and mass transfer by mixed convection in a linearly stratified stagnation flow in the presence of an internal heat generation or absorption. ^[10] studies thermal radiation effects on hydro magnetic free convection and flow through a highly porous medium bounded by a vertical plane surface, ^[11] considers the effect of radiation on unsteady natural convection in a two-dimensional participating medium between two horizontal concentric and vertically eccentric cylinders. We can only mention just a few. The bad part, which is the good part about our study, is the non-existence and or insignificant direct existence of both theoretical and empirical literature on the application of the heat equation to modelling asset price movements. Much of the work is concentrated on the application of the Black-Scholes model, see ^[12-14]. All the presented models in literature are without doubt applicable and more powerful. However, their immunity to financial diseases arising from rare events such as market crashes is really poor, hence the need of more power and more realistic forecasting models. Therefore, this study supports the use and application of physical models to modelling diffusions associated with asset prices, in particular of stocks. Heat diffusion equation is applied.

2. Main Results

We start by providing the widely used stochastic differential equation for stock price diffusions and the Brownian motion model before our main model. Stock prices are stochastic in nature and their uncertainty is not subject to vanishing in any way. As such, deterministic calculus and models cannot fully model the dynamics and diffusions associated with stock prices as they do not

capture the randomness in association of stock prices. The widely used stochastic differential equation for time change of stock prices takes the following form as in ^[12].

$$d(S_t, t) = a(S_t, t)dt + b(S_t, t)dW_t \quad (1)$$

Where, S_t is the stock is price, dW_t is innovation term representing unpredictable events that occur during the infinitesimal interval dt . Noting also that $a(S_t, t)$ and $b(S_t, t)$ are the drift and diffusion coefficients respectively. From the model (1) above, the innovation term, dW_t plays a vital role in explaining the randomness associated with stock prices, while their diffusions and dynamics are captured by $b(S_t, t)$. Moreover, ^[15] pointed out another related mean-reverting stochastic differential equation in the context of stock returns defined as:

$$dv_t = -\gamma(v_t - \theta)dt + \kappa\sqrt{v_t}dW_t \quad (2)$$

The term θ is the long-time mean of v , γ is the rate of relaxation to this mean, W_t is a standard Wiener process, and κ is the variance noise parameter. This equation is well known in financial world as the CIR process and in mathematical statistics as the Feller process, (see, ^[16-17]). Now the standard geometric (multiplicative) Brownian motion model for stock prices in the Ito form is defined as follows:

$$dS_t = \mu S_t dt + \sigma S_t dW_t \quad (3)$$

The model is analogous to (1). The subscript t indicates time dependence, μ is the drift parameter, W_t is a standard random Wiener process, and σ_t is the time-dependent volatility. Thus, our heat equation diffusion model is constructed from the basis of equations (1), (2) and (3). We intend to move from being deterministic to being stochastic by introducing the drift and the volatility coefficients to our heat diffusion model. Our main modelling process is thus well explained below:

2.1 One Dimensional Heat Equation

We firstly present the physical heat equation in one dimension as below. The model is used to model one-dimensional temperature evolution ^[18].

$$u_t = a^2 u_{xx} \quad (4)$$

The most important features of this equation are the second spatial derivative u_{xx} and the first derivative with respect to time, u_t , otherwise the derivation of the model is beyond the scope of this text. The reader is urged to consult ^[18-19]. The most important part of the model is the positive constant a^2 which is the diffusivity measure. Even though it is different from our final used model, its interpretation, relevancy and importance is similar.

It is however important to provide some contextual meaning of this simple one-dimensional equation. In

our modelling case, U is the price function of stock assets which is subject to market forces from which the diffusion/volatility component, a^2 gets support. Note that, the model is time inhomogeneous in the sense that, it depends on time t . The equation can as well be extended to a two dimensional function, see ^[20]. Next we provide our main model which better models the diffusions of the stock prices in a continuous time space. Note that the model originates from the one-dimensional heat equation defined above.

2.2 Main Model

This section presents the main diffusion model used in this study. The model takes the nature of the heat equation and is presented below:

$$\partial_t U = - \sum_{j=1}^n (\partial_{x_j} a_j(x) u) + \sum_{j,k=1}^n (\partial_{x_j} \partial_{x_k} (u_{j,k}(x) u)) \quad (5)$$

The matrix of the diffusion coefficients, μ is related to the volatility function in the standard stochastic differential equation (1) b by the following:

$$\mu(x) = b(x) \times b^*(x) \quad (6)$$

Here b^* is the transpose of the matrix b and the coefficients $a_j(x)$ correspond directly to a in the standard equation in (1) above. We are not as well interested in the derivation of the model in (5). The reader should note that the function U is the probability density function which in this case is the price probability density function. As such, if we integrate it over x , we should obtain something which is independent of t . By such, we can safely consider it as a sufficient price function. Note that, we consider our stock prices as martingales and as Markovian. Our approach as stated earlier is relying on the propositions of Louis Bachelier which one of them states that stock prices exhibit some patterns of Markov nature. In actual fact, the partial differential equation in (5) is a pure martingale. This is following the derived conditional expectation or the drift that $a_j = 0$, and if $a_j = 0$ then prices do not change over time. Non-martingale property is of course important in analysing stock prices. We will not get into detail of these. Our mission is on the diffusivity modelling of stock prices which we are now turning into in the below short paragraphed section. But before that, we provide below some evidence of the existence of the non-martingale property in equation (5). We take the expectation as follows:

If $a_j = 0$ then we have $\partial_t E(X_t) = \partial_t \int x u(x,t) dx$ which leads to the following:

$$\int \frac{x}{2} \sum_{j,k=1}^n (\partial_{x_j} \partial_{x_k} (u_{j,k}(x) u)) dx = 0 \quad (7)$$

2.3 Diffusivity of Stock Prices

The main underlying aim of this paper is to model stock price diffusions within stock markets over a continuous time space. From the standard stochastic differential equation (SDE) in (1) above, stock volatility matters much to investors especially the risk averse ones. This implies that, whatever the volatility coefficient say or suggest, investors do pay attention and respect those exhibitions by responding accordingly. The main reason is that, they want to secure their investment payoffs. It is the stock price volatility and diffusion behaviour of some sort that explains the investment status in stock assets. However, little consideration seems to be paid on the links and relations between volatility and stock diffusions. This paper is prepared for that task. We shall in this section compare the standard equation in (1) with our diffusion equation in (5) above. We aim to compare the volatility coefficients and the diffusion coefficients of the models. Such, relation is considered to be helpful in explaining and establishing the relevancy of our main model in stock markets. The essence goes as:

Using the relation in (6), we first make a supposition that $m=n=1$ such that, μ , depend on b in the relation given by $\mu=b^2$. Generally speaking, we need a matrix which is analogous to the relation, $\mu=b^2$, such that we derive a square $n \times n$ matrix from $n \times m$ of b . This is well explained in a much simpler manner in the relation (6). Further, using the moment-matching approach we can safely and clearly compare our models and their corresponding volatility and diffusion components. Suppose b is a constant and, $a=0$, then $x(0)=0$ implies that $z(0)=0$ and we get $X(t)=bZ(t)$. Thus, it follows that, $\text{Cov}(X)=E[X(t)X^*(t)]=bb^*t$. Interestingly from (5) we get the expectation

$$\partial_t E(XX^*) = \partial_t \int xx^* U(x,t) dx = \mu \quad (8)$$

which agrees with the relation in (6) We further provide some insights on the drift component. The drift component in (1) is given by $aXdt$ and it corresponds to $\partial_x a u$ in (5). This can easily be followed if a is a constant and if $b=0$. The other interesting corollary is the negative transition in the probability density function of stock prices by a factor $u(x,t)=u(x-at)$. We subsequently provide some important results below which are informative.

3. Observational Results

We provide some simple observational results following our analysis and modelling of stock prices. We note that, stock prices undergo some normal jumps which are better explained by a diffusion process defined above. The fundamental theorem of Levy we note that there

is no difference between the Wiener process and the diffusion process in their applications. The two can be used interchangeably. Thus, we note that, stock prices follow the Wiener process, when, $Z(0)=0$. Additionally, we note that the information from the observed diffusion bubbles associated with stock prices are helpful on planning in terms of asset allocation (portfolio creation), asset pricing and valuation, risk management and proper investment choice making. We noted some modelling related problems for heat equations which must be factored into account whenever our modelling makes use of the heat family of equations. Some of them include the infinite speed propagation with limited spreading, time step constraints for explicit difference methods and the smoothing property. Such features should be considered when dealing with our model defined in (5) for non-misleading results. We thus put forward that marching methods and finite differencing can be well used to solve heat diffusion equations.

4. Conclusions

We conclude that stock price diffusions can well be explained by the heat diffusion equation. Our implemented model is considered worthwhile because it is in support with the standard geometric Brownian motion model. By comparing the drift and the volatility components of (1) to the drift and diffusion properties of (5) and the relation (6) we note that these are in agreement and thus our model can better explain the diffusivity of stock prices. Our model too can be used to explain the jumps associated with the stock prices as it provides a good base for analysing stock price paths in the market under a continuous time space. Such normal and systematic jumps are without doubt informative to investors and thus should be considered. Therefore, we note that our model is more applicable and informative. This surfaces the value and power of physical models in the financial world. We thus make a recommendation of their use in financial modelling. The reader is finally recommended to read the book by ^[1], “Models Behaving Badly” for more on such modelling phenomena.

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ARTICLE

Dynamic Pricing Research for Container Terminal Handling Charges based on Demand Forecast

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ABSTRACT

A dynamic pricing model was established based on forecasting the demand for container handling of a specific shipping company to maximize terminal profits to solve terminal handling charges under the changing market environment. It assumes that container handling demand depends on the price and the unknown parameters in the demand model. The maximum quasi-likelihood estimation (MQLE) method is used to estimate the unknown parameters. Then an adaptive dynamic pricing policy algorithm is proposed. At the beginning of each period, through dynamic pricing, determining the optimal price relative to the estimation value of the current parameter and attach a constraint of differential price decision. Meanwhile, the accuracy of demand estimation and the optimality of price decisions are balanced. Finally, a case study is given based on the real data of Shanghai port. The results show that this pricing policy can make the handling price converge to the stable price and significantly increase this shipping company's handling profit compared with the original "contractual pricing" mechanism.

1. Introduction

In recent years, due to the unstable global economic development, the shipping market fluctuates wildly. Consequently, the terminal, as an essential logistics point that provides handling services to shipping companies, will bear the impact of market fluctuations. However, according to the terminal's operational data, container handling capacity has gradually become saturated, and merely attracting handling volume cannot significantly increase terminal revenue. Therefore, in the changing market environment, to develop reasonable and practical terminal handling charges is a crucial way to maximize revenue.

At present, most terminals charge for container terminal handling charges through a contractual pricing mechanism^[1]. Under this mechanism, the terminal and the shipping company negotiated and signed a contract about terminal handling charges for the next year. There may be two potential drawbacks. On the one hand, the terminal handling charges critically depend on the manager's own experience, which is difficult to reflect the labor value of terminal. On the other hand, the terminal handling charge is fixed during the contract period, which is challenging to accommodate the market changes. Therefore, the terminal needs to improve and optimize container handling charges, with the changing market environment dynamically adjusting price trends.

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The core idea of dynamic pricing is to establish the relationship between price and variable factors, such as changing periods, changing inventory, and changing demand. For terminals, the changing handling demand is an essential factor affecting the pricing of terminal handling charges. Generally, terminal handling operations are based on unit containers. On the one hand, different handling demand levels affect the composition of terminal handling costs. According to the theory of Time-driven Activity-based costing (TDABC), different types of containers are operated with different degrees of difficulty, resulting in different time consumption and thus different costs^[2]. On the other hand, the handling demand directly affects the terminal's revenue. To date, most academic studies implicitly assumed the handling demand obeys a specific distribution or a specific functional relationship, and they can fit it according to historical data^[3]. However, this method is generally applicable to a stable market environment, where the handling demand of shipping companies has little variation. The demand model can well reflect the future demands to set reasonable handling charges and improve terminal revenue. In fact, the operators of the terminal have insufficient data, and the fluctuating factors in the market environment, such as the pricing strategies of competitors, strategic behaviors of shipping companies, and market economic fluctuations, directly affect handling demand. In this case, the model of handling demand based on historical data cannot accurately reflect the shipping company's actual future demand.

This paper proposes a dynamic pricing mechanism for container terminal handling charges. This pricing mechanism is developed from the following two aspects: one is to describe the uncertainty demand of the handling volume; the other is to design a pricing policy under the uncertainty demand of the handling volume. Then, according to the physical properties and handling requirements of containers, we classify them into different types. This study's main objective is to explore the impact of different container handling charges on terminal revenue to maximize the terminal's profits, considering the terminal handling costs.

The rest of this paper is organized as follows. Section 2 is a literature review. Then, the framework of the dynamic pricing model is described in Section 3. Section 4 introduces the approach to solving the dynamic pricing problem of container terminal handling charge. Section 5 provides a case study about implementing the dynamic pricing model of the container terminal handling charge at the Shanghai Terminal. Finally, conclusions and future work are discussed in Section 6.

2. Literature Review

In port pricing studies, few studies address the pricing policy of container terminal handling charges, and mainly from qualitative research. Khalld^[4] proposed different pricing targets from the perspective of different pricing entities. From the perspective of port managers, the goal of pricing is to maximize the terminal's profits. Jia^[5] studied the price management mechanism of bulk cargo handling operation in Tianjin Port, and concluded that the existing pricing methods for port handling operation mainly include marginal cost pricing, cost-plus pricing, and game theory pricing. Wang^[6] used the analytic hierarchy process to analyze the influencing factors of container handling pricing in Port L, and the results showed that handling cost was the first important factor influencing pricing, and competition between terminals was the second key factor. Ding and Chen^[2] used price discrimination method to study the problem of container terminal handling pricing, established a quantity discount pricing model based on the assumption that the handling demand of shipping companies obeys uniform distribution, and solved the problem through particle swarm optimization. Meersman et al.^[3] discussed the principle, structure and model of port pricing and put forward the viewpoint of applying revenue management theory to port pricing. Yu and Ding^[7] introduced revenue management theory, established dynamic pricing model based on changing handling time of shipping company, and solved it by Q-Learning algorithm.

Dynamic pricing has received much research attention. Arnoud^[8] proposed the literature on dynamic pricing can roughly be classified as follows: one is models where the demand function is dynamically changing over time; the other is models where the demand function is static, but where pricing dynamics are caused by the inventory level. Further, according to whether the form of demand function is known, it can be divided into model-determined dynamic pricing which the functional form of random model is known and determined, and the dynamic pricing with uncertain models which the functional form of random model is unknown or partially known^[9]. However, Kalyanam^[10] proposed that the model-determined dynamic pricing has the following shortcomings in practical applications: compared with reality, the demand model has a certain degree of error; and the demand model reflects the historical situation, while the decision makers care about the customer's future reactions. Therefore, most researchers pay more attention to dynamic pricing research with uncertain models. Bertsimas^[11] studied the dynamic pricing in which the number of customers arriving in the

sales period was uncertain. Assuming that the demand function was linear but the parameters were unknown, the least square method was used to estimate the unknown parameters in the demand function. Levina^[12] constructed the sales process as a bernoulli process, assumed that the function form was known but the parameters were unknown, and used Bayesian theory to update the unknown parameters. Boer^[13] studied the single product dynamic pricing problem, assumed that the function form was known but the parameters were unknown, estimated the parameters by using the maximum quasi-likelihood estimation method, and proposed the control variance pricing strategy. Later, Boer^[14] extended the single-product pricing problem to multiple product dynamic pricing and proposed an adaptive pricing strategy.

In conclusion, the research on dynamic pricing has been quite completely, but on terminal handling charge is not enough. Therefore, our contributions are as follows: we apply dynamic pricing to container terminal handling

charges, introduce a model of dynamic pricing in the changing market environment, using parametric demand model describe the market process, and the value of these unknown parameters can be estimated by maximum quasi-likelihood estimation (MQLE); then propose an adaptive pricing policy to solve this problem.

3. Model Description

This paper studies by specific shipping company. We consider the handling operations of container terminal require the cooperation of m types of equipment. Classifying containers into n types, in each time period $k \in K$, the manager of terminal decides on the handling charge of each type container $p_i(k)$. After selecting the price, the manager of terminal observes the handling demand for each type of container s_{ik} . We assume that all demand can be met, in other words, terminal capacity-outs do not occur. Table 1 presents all notations used in this article.

Table 1. Notations given in the proposed model

I	Set of all the containers, $i \in I = \{1, 2, \dots, i, \dots, n\}$
J	Set of all the equipment, $j \in J = \{1, 2, \dots, j, \dots, m\}$
K	Set of all the period, $k \in K = \{0, 1, 2, \dots, k, \dots, z\}$
Θ	Set of admissible prices, $\Theta = \{1\} \times \prod_{i=1}^n [p_{li}, p_{hi}]$; where p_{li}, p_{hi} denotes the lowest and highest price for container i
$p_i(k)$	The terminal handling price of container i in period k
$P(k)$	The terminal handling price vector, $P(k) = (p_0(k), p_1(k), \dots, p_n(k))$
P^T	Transpose vector of terminal handling price
ρ	The matrix of price decisions; $\rho(k) = (P(0)^T, P(1)^T, \dots, P(k)^T)$
λ_{\min}	The smallest eigenvalue of price matrix ρ
$tr(\rho)$	The trace of price matrix ρ
P_{opt}	The correct optimal price
P_{cepq}	The certainty equivalent price
$s_{ik}(P(k))$	The handling demand for container i in period k , given price vector $P(k)$.
S_{ik}	The realized handling volume for container i in period k
r	The total expected handling revenue the specific shipping company
c_j	The unit resource-time cost of equipment j
Q_j	The total resource-time cost of equipment j
α_j	The resource-time of equipment j operating container i
C	The total expected terminal handling cost of the specific shipping company
R	The total expected terminal handling profit
R'	The total realized terminal handling profit
β	The unknown parameters in the demand model

3.1 Estimation of Container Terminal Handling Demand

In this paper, we assume that there is a functional relationship between the demand for container handling and the handling price of container terminal. Considering that estimation of demand have certain deviations in the changing market environment, therefore, this article uses parametric demand model with unknown parameter β to describe the changing market process. At the same time, the handling volume of container terminals does not obey any specific distribution, and the assumptions about this in the previous studies are ideal and simple. Therefore, assuming that the variance of the handling demand for container i is a function of expectation. The parametric model is defined as follows:

$$E(S_i(P)) = h_i(P^T \beta_i); \quad P \in \rho \quad (1)$$

$$Var[S_i(P)] = \sigma_i^2 v_i(E[S_i(P)]); \quad P \in \rho \quad (2)$$

Here, the functions h_i express the relationship between the expectation of handling demand and handling price. The functions v_i express the relationship between the variance of handling demand and expectation. The form of functions h_i, v_i are known, and parameter β is unknown.

The unknown parameters β can be estimated with maximum quasi-likelihood estimation. This is a natural extension of ordinary maximum-likelihood estimation to settings where only the function relationship between expectation and variance are known^[15]. Therefore, given the price vectors $\{P(k) : k = 1, \dots, k-1\}$ and realized handling volume $\{s_{ik} : k = 1, \dots, n; i = 1, \dots, k-1\}$, by solving equation (3) we can obtain the parameters β in period k , and denote as $\hat{\beta}_i(k)$.

$$l_{ik}(\beta_i) = \sum_{k=1}^{k-1} \frac{\partial h_i(P^T(k) \beta_k)}{\partial \beta \cdot v_i(h_i(P^T(k) \beta_i))} P(k) (s_{ik} - h_i(P^T(i) \beta_i)) = 0 \quad (3)$$

3.2 Accounting of the Terminal's Handling Profit

Considering that terminal's handling cost is an important factor influencing the pricing of terminal handling, the goal of this paper is to maximize the terminal's handling profits. In the k period, given price vector $P(k)$, the handling demand is $S(P(k))$, and the total expected terminal's handling revenue of the specific shipping company is defined as follows:

$$r(P) = \sum_i^n E[p_i \cdot S_i(P)] = \sum_i^n p_i \cdot h_i(P^T \beta_i^{(0)}) \quad (4)$$

The terminal's handling cost of the specific shipping company is calculated by TDABC method. TDABC is

a method that uses time as a driving factor to analyze costs^[2]. Usually, operating each unit of container will generate corresponding operating resource-time of each equipment. However, due to the different types of container stacks in different blocks of the terminal and they required different operating standards, this causes the operating resource-time of each type of containers is also different. Therefore, it is applicable to the cost analysis of container terminal's handling operations. Based on TDABC method, the handling cost of the specific shipping company is the sum of the total resource-time of each equipment multiplied by the corresponding unit cost. Assuming that α_{ij} , the resource-time of equipment j operating container i is constant. So, the total expected handling cost of the specific ship is defined as:

$$C = \sum_j^m \sum_i^n S_i(P) \cdot \alpha_{ij} \cdot c_j \quad (5)$$

Therefore, in k period, given price vector $P(k)$, the handling demand is $S(P(k))$, and the total expected terminal's handling profits of the specific shipping company is defined as:

$$R(P) = \sum_i^n E[p_i \cdot S_i(P)] - \sum_j^m \sum_i^n S_i(P) \cdot \alpha_{ij} \cdot c_j \quad (6)$$

3.3 Describing the Pricing Policy

At each k period, the pricing policy ϕ is a method to make a pricing decision of terminal handling based on the historical handling price of terminal $\{P(k) : k = 1, \dots, z\}$ and the realized handling volume of shipping company $\{s_{ik} : k = 1, \dots, n; i = 1, \dots, z\}$. The performance of a pricing policy ϕ is measured by the Regret, which is the loss of expected profits caused by not using the correct optimal price P_{opt} ^[14]. For a pricing policy ϕ , the Regret after z time periods is defined as:

$$Regret(z, \phi) = E \left[\sum_{k=1}^z R(P_{opt}, \beta^{(0)}) - R(P(k), \beta^{(0)}) \right] \quad (7)$$

The objective of the terminal is to find a pricing policy ϕ that attains the highest expected handling profits over z time periods. In other words, it's equivalent to minimizing Regret.

4. Adaptive Dynamic Pricing

Generally, the most simple and intuitive pricing policy based on the estimation of handling demand is: assuming that the estimation of unknown parameter in the model of handling demand is correct, based on which the optimal price can be calculated. This pricing policy is usually called certainty equivalent pricing, which is intuitive

and easy to understand but has poor performance. Den Boer ^[14] proposed an adaptive pricing policy to improve the certainty equivalent pricing. The key idea is given the estimation value of current parameter to choose the optimal price, with the additional constraint that $\lambda_{\min}(k)$, the smallest eigenvalue of the handling pricing matrix (8), grows with a certain rate (9), here is defined as the constraint function of differentiated price decision. This pricing rule balances the estimation of the parameter and the optimization of instant revenue at each period.

$$\rho(k) = \sum_{k=0}^z P(k) P^T(k) \quad (8)$$

$$\lambda_{\min}(k) \geq L(k) \quad (9)$$

Since, there is no simple explicit expression relating two consecutive smallest eigenvalues $\lambda_{\min}(k)$ and $\lambda_{\min}(k+1)$, we introduce the trace of the inverse design matrix $tr(\rho-1)$, for $\forall \rho$ conforming to the following relationship:

$$tr(\rho-1)^{-1} \leq \lambda_{\min}(\rho) \leq n tr(\rho-1)^{-1} \quad (10)$$

Therefore, the relationship between the two consecutive of the handling pricing matrix can be expressed as follows:

$$tr(\rho(k+1)^{-1} - tr(\rho(k)^{-1})) = - \frac{\|\rho(k)^{-1} \rho(k+1)\|^2}{1 + \rho^T(k+1) \rho(k)^{-1} \rho(k+1)} \quad (11)$$

A detailed pricing process with a constraint function of differentiated price decision is explained as follows:

Step 1: Initialization

Choose function $L \in \tau$; then choose $k+1$ linearly independent initial handling price vectors $P(1), P(2), \dots, P(k+1) \in \Theta$.

Step 2: Estimation

At the beginning of k period, for each type of container $i (i=1, \dots, n)$, calculate the estimated value of unknown parameter $\hat{\beta}_i(k)$ in the model of handling demand, using the equation (3).

Step 3: Pricing

(1) If for some types of container i , $\hat{\beta}_i(k)$ not exist, or the constraint $tr(\rho(k)-1)^{-1} \geq L_1(k)$ does not hold, then set $P(k+1) = P(1), P(k+2) = P(2), \dots, P(k+t) = P(t)$, where t is the smallest integer such that.

(2) If for all types of container i , $\hat{\beta}_i(k)$ exists, and the constraint $tr(\rho(k)-1)^{-1} \geq L_1(k)$ holds, then set

$P_{ceqp} = P(\hat{\beta}(k))$, and consider the following cases:

(2a) If the constraint $tr((\rho(k) + P_{ceqp} P_{ceqp}^T)^{-1})^{-1} \geq L_1(k+1)$ holds, then choose $P(k+1) = P_{ceqp}$.

(2b) If the constraint $tr((\rho(k) + P_{ceqp} P_{ceqp}^T)^{-1})^{-1} \geq L_1(k+1)$ does not hold, then choose $P(k+1)$ that maximizes (12) provided there is a feasible solution.

$$\max_{\rho \in \Theta} R(\rho, \hat{\beta}(k)) \quad s.t. \frac{\|\rho(k+t)^{-1} \rho\|^2}{1 + \rho^T \rho(k)^{-1} \rho} \geq \frac{L_1(k)}{L_1(k)^2} \quad (12)$$

(2c) If the constraint $tr((\rho(k) + P_{ceqp} P_{ceqp}^T)^{-1})^{-1} \geq L_1(k+1)$ does not hold, and (12) has no feasible solution, then put $P(k+1) = P(1), P(k+2) = P(2), \dots, P(k+t) = P(t)$, where t is the smallest integer such that.

5. Case Study

In this section, taking a terminal handling company in Shanghai port as an example, the dynamic pricing model is analyzed based on the estimation of handling demand of a specific shipping company. The data of this research comes from the operational data of the handling terminal company in 2017. Moreover, the proposed adaptive pricing algorithm is implemented in Matlab R2017a.

5.1 Basic Parameter Setting

According to the process of handling operation of the container terminal, the equipment on the terminal is divided into three types of resource groups ($j=1,2,3$): Yard crane, Truck and Quay crane. According to the physical characteristics and circulation direction, containers are divided into six types ($i=1, \dots, 6$): empty containers for export, full containers for export, empty containers for import, full containers for import, dangerous containers for export and special refrigerators containers for export. According to the data of the terminal's cost in 2017, c_j , the cost of unit resource-time of equipment j , and α_{ij} , the resource-time of equipment j operating container i are calculated as shown in Table 2. The data of lowest and highest handling price for container i are shown in Table 3.

Table 2. The cost of unit resource-time of equipment j (min/TEU) and The resource-time of equipment j operating container i (yuan/h)

a_j/min	Export-empty	Export-full	Import-empty	Import-full	Dangerous	Special	c_j
Yard crane	5	8	4	8	9	1	522
Tuck	21	13	16	18	14	26	157
Quay crane	3	2	2	2	1	3	1704

Table 3. The lowest and highest handling price for various containers (yuan/TEU)

$p(k)$	Export-empty	Export-full	Import-empty	Import-full	Dangerous	Special
pl	390	480	390	420	550	500
ph	1000	1000	1000	1000	1000	1000

5.2 Pricing Strategy Analysis

In this section, taking a specific shipping company as the research object, the interval between the shipping company's two arrivals at the terminal is a decision-making period. The demand for each container i is normally distributed with expectation and variance given by:

$$E[S_i(P)] = \beta_{i0} + \beta_{i1}p_1 + \cdots + \beta_{in}p_n \quad (i = 1, \dots, 6)$$

$$\text{Var}[S_i(P)] = \sigma_i^2 \quad (i = 1, \dots, 6)$$

The set τ of constraint function of differentiated pricing decision in adaptive pricing is $L = \alpha * \sqrt{k \log(k)}$ ($0 \leq \alpha \leq 1$). First, take $\alpha=0.5$, according to the procedure of adaptive pricing in Section 4, the estimated handling volume of each type of container about the shipping company in the next period is $S=(10,415,117,36,333)^T$; the optimal handling pricing decision is $P_{opt} = (650,750,639,772,800,896)^T$; the expected handling profit is 476,300 yuan, which is an increase of 18,600 yuan compared with the actual profit of 457,400 yuan. Then, one year is set as a planning period to predict the demand of handling volume and determine the price about the handling operations of the shipping company at the terminal. The operating results are shown as (a)-(d) in Figure 1. Figure(a) shows a sample path of $tr(p(k)^{-1})^{-1}$ divided by $\sqrt{k \log k}$, it can be seen that the ratio of the two converges to 0.05, indicating that $L = 0.05 * \sqrt{k \log(k)}$, the constraint function of differential price decision of adaptive dynamic pricing policy is reasonable. Figure (b) shows the squared norm of the difference between

the parameter estimates and the true parameter, from that the adaptive dynamic pricing policy has a better convergence effect and the parameter estimation can converge to the real value. Figure (c) shows Cumulative Regret and Figure (d) shows the sample path of Regret divided by $\sqrt{k \log k}$, illustrating that the adaptive dynamic pricing policy has a good optimization effect and can obtain the correct optimal price.

Further, changing the value of coefficient α in constraint function of differential price decision in the adaptive pricing policy, and take $\alpha \in \{0.1, 0.3, 0.5, 0.7, 0.9\}$. The coefficient α is larger, the difference of handling price between the shipping company arriving at the terminal for two adjacent periods is greater. Observe the change of the bound of cumulative Regret and the handling profit of specific shipping company. The calculation results are shown in Table 4. The results show that: for the upper bound of the cumulative Regret, it decreases first and then increases with the increase of coefficient α , when the coefficient α changes from 0.1 to 0.5, the upper bound of cumulative Regret drops to 1.3269 million yuan; changing from 0.5 to 0.9, the upper bound of cumulative Regret increased to 1.4835 million yuan. For handling profit of specific shipping company, it also increases first and then decreases with the increase of coefficient α , when the coefficient α changes from 0.1 to 0.5, the growth of handling profit of specific shipping company increases to 1.8268 million yuan; changing from 0.5 to 0.9, the growth of handling profit of specific shipping company decreased to 0.9219 million yuan.

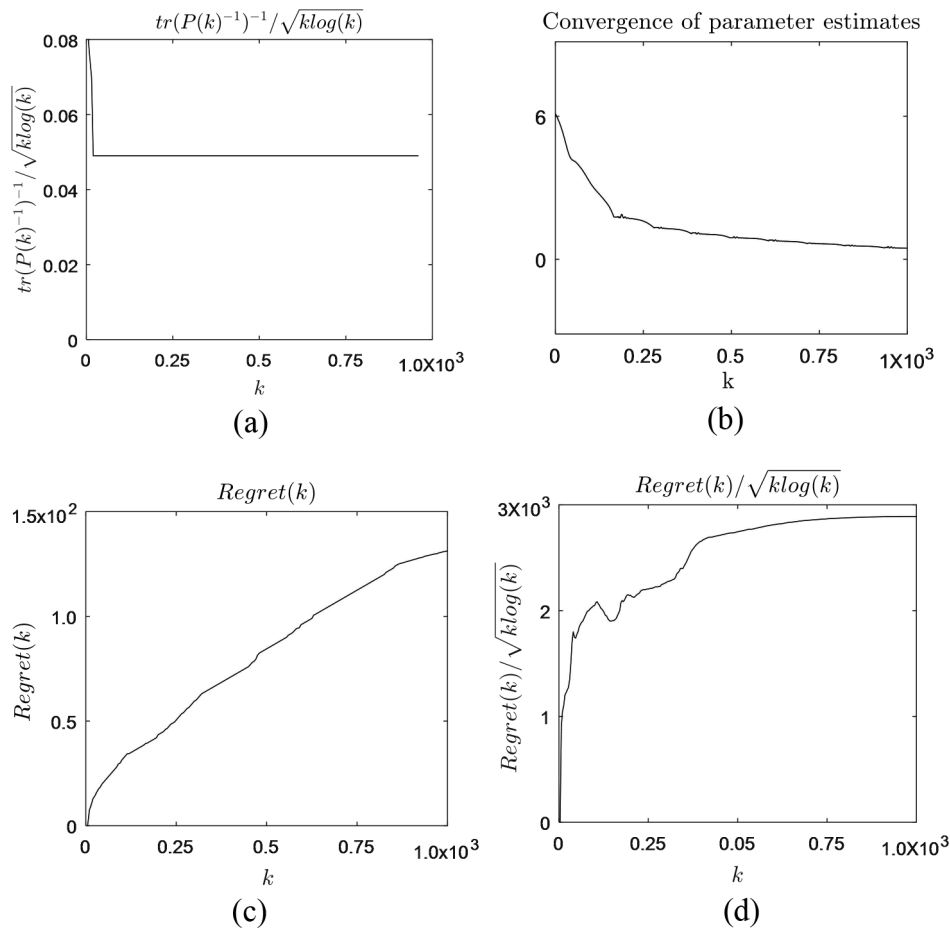


Figure 1. The solution results are shown in the diagram

Table 4. The upper bound of cumulative Regret and handling profit (wan yuan)

α	0.1	0.3	0.5	0.7	0.9
Upper bound	149.74	144.87	132.69	139.11	148.35
R	6897.56	7098.99	7200.93	7162.22	7090.44

6. Conclusion

This paper proposes a dynamic pricing model for terminal handling charges based on handling demand estimation, using the maximum quasi-likelihood estimates of the unknown parameters in the demand model and adaptive pricing algorithm to solve the pricing process. The computational results suggested that: (1) The adaptive pricing policy can converge the terminal handling charges to the correct price, balance the accuracy of the estimation of handling demand and the optimality of pricing, and increase the terminal handling profits compared with the contractual pricing mechanism. (2) The range of

difference of handling price in adjacent periods will affect the variation of terminal handling profit and the upper bound of accumulated Regret. For example, the difference in handling price between the two adjacent periods changes slightly, and the handling profit decreases on the contrary. However, the difference in handling price is more tremendous; terminal profit growth is not necessarily more significant. Therefore, for the terminal, the constraint of the price difference should be determined according to the shipping company's actual situation. In conclusion, the adaptive dynamic pricing policy with constraints of differentiated price decision is conducive to improving the terminal's revenue and has specific reference value for pricing of terminal handling.

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ARTICLE

Spatial Dislocation Analysis of Tourism Economy and Its Influencing Factors in Jiangsu Province

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ABSTRACT

Taking 13 prefecture-level cities in Jiangsu Province as the research object, based on the theory of spatial dislocation, the gravity model and two-dimensional composite matrix method are used to analyze the spatial dislocation between tourism resources, permanent population and other factors in Jiangsu Province and tourism revenue. The results show that the population center, the center of tourism resources, the center of tourist numbers, the center of economic development, and the center of tourism revenue of Jiangsu Province are all biased toward the southern part of Jiangsu Province. From the analysis of four sets of two-dimensional composite matrixes, 13 prefecture-level cities have synchronized coordination and also have positive and negative dislocation types. Southern Jiangsu has the best synchronization and coordination, and northern Jiangsu has a strong negative dislocation trend; the combination of tourist numbers and tourism revenue is the strongest, but the dislocation is weak; population and tourism revenue have a strong positive dislocation trend; there is a strong negative dislocation trend between economic development and tourism revenue; the matrix combination of Nanjing, Wuxi and Suzhou has good synchronization; the city of Xuzhou in northern Jiangsu has a strong negative dislocation. In view of the results of spatial dislocation analysis, suggestions for improvement and optimization are put forward to promote the high-quality development of tourism in Jiangsu Province.

1. Introduction

The unbalanced development of regional tourism economy is a common phenomenon and a hot topic in academic research. Tourism revenue can reflect the operating conditions of regional tourism economy, and comprehensively measure tourism economic activities

and their effects^[1]. It is affected by factors such as high-level tourism resources, number of tourists^[2], GDP^[3], etc. The study of tourism economy from a spatial perspective is the method currently adopted by most scholars, and there are many research results. Scholars have carried out rich research on the spatial distribution of resources, the temporal and spatial evolution of scenic spots, and

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the efficiency of tourism economy. Kain first proposed the spatial dislocation theory in the 1960s, reflecting the theoretical hypothesis of the living and employment opportunities of disadvantaged groups^[4]. It was gradually used in the fields of geography and economics^[5]. The methods in the empirical study of spatial dislocation are mostly regression models, which are combined with GIS and spatial measurement^[6]. Most domestic researches on spatial dislocation are based on specific cities or regions. Northeast, western, Shanxi, Anhui, Henan and other places are common research objects. Many scholars selected various influencing factors based on the spatial dislocation theory, and use the gravity model and two-dimensional combination matrix to conduct research: Deng etc al. studied the spatial dislocation of tourism resources, location, and inbound tourism revenue in 31 provinces on the mainland^[7]; Weng etc al. further included regional tourism services and cultural industries into the dislocation research objects^[8]; Ren used star hotels as a factor in analyzing the dislocation of Zhejiang's tourism space^[9]; Wang etc al. considered the impact of demographic factors on the tourism performance of Anhui Province^[10]. Therefore, it can be seen that based on the theory of spatial dislocation, the use of gravity model and two-dimensional combined matrix analysis method is the current mainstream trend of analyzing regional tourism spatial dislocation, which has strong persuasiveness and empirical evidence.

Located in the Yangtze River Economic Zone, Jiangsu Province is an important part of the Yangtze River Delta, and its comprehensive economic development level ranks among the top in the country. There are rich tourism resources, many types of tourism, natural ecology, red imprints, world heritage, etc., and the westward journey culture, ocean culture, red culture and tourism are fully integrated. One of the key points of Jiangsu Province's work in 2020 is to promote the high-quality development of the cultural and tourism industry. On August 20, 2020, General Secretary Xi Jinping mentioned in his speech at the symposium on solidly promoting the integrated development of the Yangtze River Delta that one of the measures to promote integrated development is to improve the quality of urban development in the Yangtze River Delta. The high-quality development of tourism is an important part of the integration of the Yangtze River Delta and the improvement of urban quality. As of the end of 2019, there were 615 A-level scenic spots in Jiangsu Province; in 2019, the total tourism revenue was 1432.16 billion yuan and the number of domestic tourists received was 880 million, all of which increased year by year. However, judging from the development of the tourism

industry in Jiangsu Province, the total tourism revenue of Nanjing in 2019 reached 27,849,500 yuan, while the total tourism revenue of Suqian in 2019 was only 3.36 million, which is only equivalent to 12% of Nanjing. Therefore, there are differences in the development of tourism economy among regions, and the overall development of the tourism industry is not coordinated.

However, there are few studies on the spatial dislocation of tourism development in Jiangsu Province. Existing studies have examined the spatial dislocation relationship between tourism resources, tourism reception capacity and tourism performance^[11]. Few other factors are included in the scope of research. Therefore, based on the theory of spatial dislocation, this article explores the spatial dislocation between resources, population, economic development, tourist numbers and tourism revenue, and studies the imbalances that exist in various cities. The paper also combines the gravity model and two-dimensional combination matrix to analyze deeply the degree of spatial dislocation among various elements, and finally put forward suggestions to optimize the spatial dislocation, which is important for the future high-quality development of the tourism industry in Jiangsu Province, giving full play to resource advantages, increasing domestic and foreign visibility, and meeting people's diversified tourism Demand.

2. Research Methods

This paper standardizes the tourism resources, permanent population, economic development level, total number of tourists, and total tourism revenue to obtain the index of each indicator. At the same time, using the gravity model, the center of tourism resources, population, and economy of Jiangsu Province are obtained, which are used to conduct macro spatial dislocation analysis; finally, the tourism resource index, population index, economic development level index, tourist number index and total tourism revenue index are respectively formed into a two-dimensional matrix for further analysis the degree of spatial dislocation in the relevant aspects of the prefecture-level cities in Jiangsu Province. Tourism resource indicators are analyzed from the perspective of A-level scenic spots. A-level scenic spots are highly representative in measuring the quality of regional scenic spots, displaying characteristic resources, and laying the foundation for the development of tourism economy^[12]. The level of economic development is measured by per capita GDP, which is generally calculated based on the permanent population, so the permanent population data is used for the demographic factor; the total number of tourists and the total tourism revenue are the sum of the number of domestic

and foreign tourists and revenue respectively.

2.1 Quantification of the Abundance Value of Tourism Resources

The abundance of tourism resources affects the economic benefits of the region, which is related to people's travel experience and satisfaction, and affects tourists' behavior intentions such as willingness to revisit. In order to facilitate the subsequent index analysis, the abundance value of the tourism resources of each city is quantified here to reflect the quality and quantity of the tourism resources of each city. The formula is: 0.5

$$R_i = 5.0N_5 + 2.5N_4 + 1.75N_3 + 0.5N_2 + 0.25N_1 \quad (1)$$

among them: R_i is the quantified value of tourism resources in prefecture-level city of i ; $N_1 \sim N_5$ respectively indicate the number of A-5A-level scenic spots in Jiangsu Province by the end of 2019, the data comes from the official website of the Department of Culture and Tourism of Jiangsu Province; we refer to previous research models^[13], 0.25, 0.5, 1.75, 2.5, 5.0 represent the weight of the A-5A-level scenic spot.

2.2 Research Index

Incorporating the quantified value of tourism resources, total tourism revenue, permanent population, economic development, total number of tourists and other data into formula (2)^[14], and carrying out range standardization processing to obtain the index value of each indicator, which are used as the measurement of analysis index. The original data comes from the 2019 National Economic and Social Development Statistical Bulletin of Jiangsu Province.

$$M_x = \frac{Q_i - Q_{\min}}{Q_{\max} - Q_{\min}} \times 100 \quad (2)$$

among them: M_x indicates the index value of each indicator; Q_i indicates the value of an indicator in a prefecture-level city i ; Q_{\min} indicates the minimum value of an indicator in 13 prefecture-level cities; Q_{\max} represents the maximum value of an indicator in 13 prefecture-level cities.

2.3 Gravity Model

Gravity model is often used in the study of regional economic spatial structure to reflect the location relationship and spatial organization of economic things in the carrier of geographic space^[15]. Emphasis indicates the point that can maintain balance in all directions in a certain area^[16]. The gravity model can be used to calculate the center of gravity of tourism resources, population,

economic development, total number of tourists, and total tourism revenue in Jiangsu Province. The specific calculation formula is as follows^[17]:

$$X_R = \frac{\sum_{i=1}^n (M_i \times X_i)}{\sum_{i=1}^n M_i} \quad Y_R = \frac{\sum_{i=1}^n (M_i \times Y_i)}{\sum_{i=1}^n M_i} \quad (3)$$

Among them: X_R, Y_R indicates the latitude and longitude of the center of gravity of the spatial distribution of an index in Jiangsu Province; M_i indicates the value of an index in city i ; X_i, Y_i indicates the latitude and longitude of the administrative center of gravity in city i ; n is the number of prefecture-level cities in Jiangsu Province, that is, $n=13$.

2.4 Two-dimensional Combination Matrix

The gravity model shows the distribution of the center of gravity and the degree of spatial dislocation of various indicators from a macro perspective^[12]. In order to understand the specific spatial dislocation of tourism resources, permanent population, economic development level, total number of tourists and total tourism revenue in 13 prefecture-level cities, we need to use Two-dimensional combination matrix; according to the index size of the indicators, they are divided into different levels, and then the above four types of indicators and tourism revenue are respectively formed into a matrix, and the dislocation relationship between each level city is analyzed in detail, and also the spatial dislocation type is summarized.

3. Results

3.1 Analysis of various indexes

Through the above calculation formula, the tourism resource abundance index, tourism revenue index, population abundance index, economic development index and tourist population index can be obtained respectively (see Table 1). From the perspective of tourism resource abundance index, Suzhou has the highest resource index. Although it is not the prefecture-level city with the most scenic spots, it has a certain resource attraction. At the same time, its permanent population abundance index is also the highest. Regarding the economic development index, Wuxi has the highest per capita GDP index, followed by Suzhou and Nanjing, and the gap between the indices is large; in terms of tourist number index, the provincial capital city Nanjing has the highest tourist number index, Suzhou ranks second, and Suqian index the lowest; tourism revenue can reflect tourism benefits, Nanjing's tourism has developed well, ranking first. Followed by

Table 1. Spatial dislocation index of tourism in prefecture-level cities in Jiangsu Province

City	Index					
	Quantification of tourism	Abundance index of tourism resources	Tourism revenue Index	Population abundance index	Economic Development Index	Tourist Attendance Index
Nanjing	105.000	60.182	100.000	70.185	87.799	100.000
Yangzhou	96.250	49.544	27.530	17.829	56.399	41.699
Zhenjiang	55.500	0.000	28.118	0.000	56.485	36.433
Taizhou	70.750	18.541	3.186	18.984	40.870	3.108
Wuxi	113.500	70.517	70.516	44.895	100.000	62.631
Changzhou	63.250	9.422	35.182	20.307	79.863	43.547
Suzhou	137.750	100.000	98.614	100.000	99.317	90.979
Nantong	87.000	38.298	18.240	54.522	55.887	20.884
Xuzhou	110.750	67.173	21.158	74.499	15.614	30.008
Lianyungang	67.750	14.894	10.287	17.326	5.717	11.902
Huaian	65.250	11.854	5.475	22.913	13.396	7.348
Yancheng	93.500	46.201	3.508	53.076	13.908	7.765
Suqian	74.000	22.492	0.000	22.983	0.000	0.000

Suzhou and Wuxi. The data in the table reflects that there is a large gap in the tourism development of various cities in Jiangsu Province, there is a certain imbalance, and there is a certain spatial dislocation between resources and other factors and revenue.

3.2 Overall Analysis of the Province's Spatial Dislocation

Jiangsu Province is located on the eastern coast of the mainland, between 116.18°~121.57° east longitude and 30.45°~35.20° north latitude. According to the calculation of the gravity model, the center of tourism resources in Jiangsu Province is located at 32.46° north latitude and 119.67° east longitude; the center of economic development is at 31.99° north latitude and 119.85° east longitude; the population center is at 32.54° north latitude and 119.66° east longitude; the center of tourist number is at 32.08° north latitude and east 119.66° longitude; the center of tourism revenue is at 31.98° north latitude and 119.71° east longitude. The center of gravity of tourism resources and population is located in Yangzhou City, and the center of population is located to the north and west of tourism resources. The center of tourism population and tourism revenue are located in Zhenjiang City. The center of tourism revenue is close to Changzhou City, and the center of economic development gravity lies in Changzhou City, but also close to Zhenjiang City. It can

be seen that the spatial dislocation of population, tourism resources and tourism revenue is quite significant, and there is a certain degree of disharmony; the spatial dislocation of tourist number, economic development and tourism revenue is relatively small, and the five centers of gravity are generally biased towards southern Jiangsu. The development of tourism in southern Jiangsu has obvious advantages in all aspects. The per capita GDP of Nanjing, Suzhou, Wuxi, Changzhou and other places are in the forefront of Jiangsu Province, and they are well-known at home and abroad. And the number of tourists is increasing, and the number of A-level tourist attractions has reached more than 50, with abundant tourist resources. Compared with northern Jiangsu, the population center of gravity is closest to northern Jiangsu. This is because the population in northern Jiangsu is relatively concentrated. Although there are many tourism resources, it may cause uncoordinated tourism revenue and economic development due to traffic location and popularity.

3.3 Spatial Combination Type Analysis

3.3.1 Analysis on the Spatial Misalignment of Tourism Resources and Tourism Revenue

Tourism resources are the gospel of the development of the tourism industry^[19] and unique production factors of the tourism industry^[20], which affects tourists' willingness

to play. Through the two-dimensional matrix analysis of tourism resources and tourism revenue, Table 2 can be obtained.

It can be seen that Wuxi and Suzhou are rich in tourism resources, and tourism revenue has increased simultaneously, and the two have reached the best match. There are more than 50 A-level scenic spots in the two places, rich in resources. Wuxi is a famous historical and cultural city in the world, Suzhou gardens are included in the world cultural heritage, and the transportation facilities in the two places are very complete, so the tourism development advantages are significant. Nanjing is rich in tourism resources, but the tourism revenue is high, and the two are the matching positive and dislocation areas; Nanjing is the capital city of Jiangsu Province and the ancient capital of the Six Dynasties. It has a strong history and culture, many historical attractions, and complete transportation facilities. Although the amount of resources is not as good as Wuxi and Suzhou, it is in line with Wuxi Suzhou in terms of tourism revenue; Yangzhou's tourism resources and revenue are both in the middle area, reaching the middle area that matches the two. Yangzhou is rich in forests, gardens, food and other cultures. Tourism incorporates the concept of ecological civilization, and it has become a general trend for current tourists to pay attention to environmental protection and ecology; Xuzhou has a relatively high degree of tourism resources, but tourism revenue is low. The two belong to the matching negative dislocation area. The number of A-level tourist attractions in Xuzhou has reached 64, ranking first in Jiangsu Province. However, due to the geographical location and the focus on industry in regional development, tourism revenue and resources do not match. Nantong and Yancheng have moderately rich tourism resources, but in terms of tourism revenue, one is in the lower position and the other is in the lower position. The

degree of spatial dislocation in Nantong is relatively low, while that in Yancheng is relatively high. Nantong A-level scenic spots account for a large proportion of 3A-level scenic spots. 3A-level scenic spots are not as well-known as 4A and 5A-level scenic spots, so it may slightly restrict the development of local tourism; Yancheng is located in the northern part of Jiangsu, although there are large areas of coastal beaches, and it has the only world natural heritage site in Jiangsu for migratory birds in China's Yellow (Bo) Sea. However, due to geographical location and other factors, tourism development does not have great advantages; Huai'an and Lianyungang show a synchronized trend of tourism resources and tourism revenue, which is a double low Area. The number of A-level scenic spots in Huai'an and Lianyungang are at the end of Jiangsu Province, but Huai'an has red tourist attractions such as Zhou Enlai's former residence, and Lianyungang's Huaguo Mountain and other tourist attractions are popular, so tourism revenue and tourism resources have reached a positive match; The tourism resources and tourism revenue of Taizhou and Suqian show a negative dislocation; Changzhou and Zhenjiang have low tourism resource richness, but the tourism revenue is in the middle and low locations respectively, which belong to the matching negative dislocation area; Changzhou and Zhenjiang are close to the provincial capital cities Nanjing, therefore, will indirectly promote the development of tourism in the two places, and tourism revenue and tourism resources will not match.

3.3.2 Analysis on the Spatial Misalignment of Permanent Residents and Tourism Revenue

The factor of permanent resident population is an important consideration in the development of regional tourism economy. It can bring the scale of tourist source to the

Table 2. Two-dimensional combination matrix of tourism resources and tourism revenue

		Tourism revenue Index				
		High (>65)	Higher (45-65)	Medium (25-45)	Lower (5-25)	Low (<5)
Abundance index of tourism resources	High (>70)	Wuxi, Suzhou				
	Higher (50-70)	Nanjing				Xuzhou
	Medium (30-50)				Yangzhou	Nantong Yancheng
	Lower (10-30)					Huaian, Lianyungang Taizhou, Suqian
	Low (<10)				Changzhou	Zhenjiang

Table 3. Two-dimensional matrix of permanent residents and tourism revenue

		Tourism revenue Index				
		High (>65)	Higher (45-65)	Medium (25-45)	Lower (5-25)	Low (<5)
Population abundance index	High (>70)	Nanjing, Suzhou			Xuzhou	
	Higher (50-70)				Nantong	Yancheng
	Medium (30-50)	Wuxi				
	Lower (10-30)				Yangzhou, Changzhou	Lianyungang, Huaian, Taizhou, Suqian
	Low (<10)				Zhenjiang	

Table 4. Two-dimensional combination matrix of economic development and tourism revenue

		Tourism revenue Index				
		High (>65)	Higher (45-65)	Medium (25-45)	Lower (5-25)	Low (<5)
Economic Development Index	High (>70)	Nanjing, Suzhou, Wuxi		Changzhou		
	Higher (50-70)			Zhenjiang	Nantong, Yangzhou	
	Medium (30-50)					
	Lower (10-30)					
	Low (<10)					

tourism market and support the operation and development of scenic spots^[20]. Through two-dimensional matrix analysis, a two-dimensional matrix of permanent residents and tourism revenue is obtained (see Table 3).

Nanjing and Suzhou's population and tourism revenue have reached the best match and belong to the double high area; Nanjing and Suzhou have the top two permanent residents in the province in 2019, and they have huge development space and potential; The population and tourism income of Lianyungang and Huai'an have also reached the same level, and the population and tourism revenue are both low; Wuxi's population abundance is medium, but tourism revenue is high, and it belongs to a matching positive dislocation area, thanks to Wuxi's good geographical location and rich tourism resources; Xuzhou is densely populated, but its tourism income is low, which is a matching negative dislocation area; Nantong has a high population abundance, but the tourism revenue is also low, which belongs to the matching negative dislocation

area; Yangzhou and Changzhou have low permanent population abundance, but tourism revenue is in the Medium, and the two are matched positive dislocation areas; Taizhou and Suqian have low population abundance indexes, and tourism revenue is at a low level, which belong to matching negative dislocation areas; finally, Zhenjiang is not densely populated, but tourism revenue is at a medium level. It belongs to positive and wrong matching.

3.3.3 Analysis on the Spatial Misalignment of Economic Development and Tourism Revenue

GDP per capita can measure people's lives and is also an important cornerstone of tourism development. The two-dimensional matrix model of economic development and tourism revenue is obtained through the combination of two-dimensional matrix (see Table 4).

The economic development and tourism revenue of Nanjing, Suzhou and Wuxi are at a high level, and the

two have reached the best match. The per capita GDP of these three cities is also the top three in Jiangsu Province, and the level of economic development is high, thus to a large extent promoting the development of tourism; Suqian's economic development and tourism revenue are both low, and it is in a double-low area; Huai'an and Xuzhou's economic development and tourism revenue are both low, and the two have reached a match; in addition, The economic development level of Changzhou and Zhenjiang has reached a relatively high level, but the tourism revenue is at a medium level, which is a matching negative dislocation area; the economic development level of Nantong, Yangzhou, and Taizhou is above the medium level, but the tourism revenue level is low, which belongs to the matching negative dislocation zone; Yancheng's economic development and tourism revenue are also in a negative dislocation zone; finally, Lianyungang's economic development level is low, but it has low tourism revenue, which is a positive dislocation of matching. Therefore, there is a great correlation between the level of economic development and tourism revenue.

3.3.4 Analysis of the Spatial Misalignment of Tourist Number and Tourist revenue

The number of tourists reflects the attractiveness of regional tourism and is a direct prerequisite for bringing tourism revenue. Table 5 shows the two-dimensional matrix of the number of tourists and tourism revenue.

It can be seen that the number of tourists and tourism revenue in the 10 places of Suzhou, Nanjing, Zhenjiang, Yangzhou, Changzhou, Lianyungang, Nantong, Suqian, Taizhou and Yancheng have reached synchronization and coordination. Nanjing and Suzhou are in the double high

districts, thanks to the good economic development and the endowment of resources, and the number of tourists in 2019 is the top two in the province; Zhenjiang, Yangzhou and Changzhou belong to the middle-range areas that match the two, and Suqian, Taizhou and Yancheng are in the double low zone. The number of tourists in Wuxi is relatively high and the level of tourism revenue is high, both of which belong to the positive dislocation zone; the number of tourists in Xuzhou is medium, but the level of tourism revenue is low, which is a negative dislocation zone; the number of tourists in Huaian is low, but the level of tourism revenue is low, which is the positive dislocation area. It can be seen that the number of tourists in general may be positively correlated with tourism revenue, but after comprehensive consideration of other factors, the mechanism of action will change.

4. Conclusions and Suggestions

4.1 Conclusions

From the analysis of the gravity model, it is concluded that the population center of gravity and the center of tourism resources of Jiangsu Province are both in Yangzhou City, and the center of population and resources are relatively close; the center of tourist population and tourism revenue are located in Zhenjiang City; the center of economic center is located in Changzhou City. And the distribution of the five centers of gravity is biased towards the southern part of Jiangsu Province. The population center, the center of resources, the center of population, and the center of economic center and tourism revenue all have obvious spatial dislocation.

From the analysis of the two-dimensional combina-

Table 5. Two-dimensional combination matrix of tourist numbers and tourist revenue

		Tourism revenue Index				
		High (>65)	Higher (45-65)	Medium (25-45)	Lower (5-25)	Low (<5)
Tourist Attendance Index	High (>70)	Suzhou, Nanjing				
	Higher (50-70)	Wuxi				
	Medium (30-50)	Zhenjiang, Yangzhou, Changzhou				
	Lower (10-30)	Lianyungang, Nantong				
	Low (<10)	Huaian, Suqian, Taizhou, Yancheng				

tion matrix, in the combination of tourism resources and tourism revenue, the synchronization areas of the two are mainly in Wuxi, Suzhou, Yangzhou, Huai'an and Lianyungang, and the double high area is in the southern area of Jiangsu (Wuxi, Suzhou), and the middle area is in central Jiangsu (Yangzhou), and the double lower area is in northern Jiangsu (Huai'an, Lianyungang); the positive dislocation area has only three southern Jiangsu cities, Nanjing, Changzhou and Zhenjiang; the rest are negative dislocation areas, distributed in Suzhonghe Northern Jiangsu. In the spatial combination of resident population and tourism revenue, the synchronization area of the two is reflected in the four places of Nanjing, Suzhou, Lianyungang and Huai'an. Among them, the double high area is located in southern Jiangsu (Nanjing, Suzhou), and the lower double area is located in northern Jiangsu (Lianyungang), Huaian), most of the positive dislocation areas are distributed in southern Jiangsu, while the negative dislocation areas are distributed in central Jiangsu and northern Jiangsu. In the combination of economic development and tourism revenue, the synchronization areas of the two are mainly in southern Jiangsu (Nanjing, Suzhou, Wuxi) and northern Jiangsu (Huai'an, Xuzhou, Suqian), a total of 6 cities, the positive dislocation area is only Lianyungang, the remaining 6 cities are all negative dislocation areas, distributed in southern Jiangsu, central Jiangsu and northern Jiangsu. Finally, in the spatial combination of the number of tourists and tourism revenue, Synchronous coordination accounted for the majority, a total of 10 cities, concentrated in Southern Jiangsu and Northern Jiangsu; there are 2 positive dislocation areas, and only Xuzhou is the negative dislocation area.

In summary, the four spatial combinations of Nanjing, Wuxi and Suzhou are all coordinated or positively dislocated. The tourism industry is developing well and resources can be fully and effectively utilized. Two spatial combinations in Yangzhou are in the medium zone, and the other two combinations are in the negative dislocation zone; Changzhou is mostly in the negative dislocation area; Zhenjiang's four spatial combinations are involved in the positive and negative dislocation areas; the central Jiangsu cities Nantong and Taizhou are mostly negative dislocation areas; The tourism development trend of the five cities in northern Jiangsu is not very good, and most of them are negative dislocation areas. Therefore, in view of the different spatial dislocation combinations of different cities, it is necessary to put forward countermeasures and suggestions to help coordinate the development of tourism in various cities, promote the rational use of resources, increase tourism brand awareness, narrow the gap between cities, and work

together to improve tourism in Jiangsu Province High-quality development of the industry.

4.2 Suggestions

Based on the analysis of the above results and conclusions, three regions of Southern Jiangsu, Central Jiangsu, and Northern Jiangsu are divided into three areas to propose countermeasures for spatial dislocation.

The southern Jiangsu region (Nanjing, Wuxi, Changzhou, Suzhou and Zhenjiang) is a region with a relatively high level of economic development in Jiangsu Province, with convenient transportation, high per capita GDP, high disposable revenue of residents, and relatively high level of consumption. The tourism industry in Nanjing, Wuxi and Suzhou should continue to maintain a good momentum, make full use of their own advantages, innovate, develop creative tourism projects, strengthen integrated marketing, and at the same time radiate their own value to the neighboring cities- Zhenjiang and Changzhou, driving the development of two places. Zhenjiang and Changzhou do not have many tourism resources, but they are showing good trends in terms of number of tourists and revenue. Therefore, these two cities must play a role in promoting the tourism activities of the local permanent population on the one hand, and on the other hand, the management of tourist attractions should be more precise and linked, accurately locate the target group, and create a linked boutique route. At the same time it is very important to make good use of the resources of surrounding cities.

The three regions of Central Jiangsu (Yangzhou, Taizhou and Nantong) have their own advantages in the development of tourism. Yangzhou's resources and revenue are relatively matched, and 3A-level scenic spots account for the proportion, but economic development and tourism performance are not balanced, so it can give full play to its own advantages, strengthen the tourism promotion of local people, create distinctive tourism resources, and form a unique tourism brand; Taizhou and Nantong, where most of the combinations are negative dislocation areas, should increase the promotion of tourism resources and organize innovative tourism activities to enhance tourist attraction.

The development of tourism in northern Jiangsu (Huai'an, Lianyungang, Yancheng, Xuzhou and Suqian) is restricted by many factors. The level of economic development is relatively backward, the geographical position is not good, the transportation is not convenient, the tourism reputation is low, and the attraction of resources is slightly less, so tourism revenue is also affected. Therefore, the most important thing is that each

region should identify its own tourism development model, form a clear positioning, and achieve a balance between all walks of life. Most of the five places in northern Jiangsu have memories of the Red Revolution and a strong traditional cultural atmosphere. 2021 will be the 100th anniversary of the founding of the Communist Party of China. Red tourist attractions can rationally and scientifically plan tourism activities, make overall arrangements, and enhance the attractiveness of resources. The per capita GDP of northern Jiangsu is relatively low, so the consumption level of residents is slightly lower. The local permanent population may have a weaker willingness to travel. Therefore, improving the local economy and driving the development of the tourism industry is the primary task; secondly, the government and tourism enterprises should focus on analyzing tourist crowds and strengthen the marketing of tourist sources. In addition, the railway construction in the northern part of Jiangsu Province is becoming more and more perfect. Many lines will directly connect to the southern part of Jiangsu in the future. Therefore, the tourist accessibility of northern Jiangsu cities will be significantly improved, and the development of tourism economy is just around the corner.

In summary, the development of tourism economy in Jiangsu Province is affected by many internal and external factors, not only the factors mentioned in this article, but the mechanism of action between factors that can promote the evolution of the spatial pattern of the tourism industry. The phenomenon of spatial dislocation needs to be improved and optimized for a long time. There are more influencing factors that deserve to be discussed in the future, and we are committed to enriching the theory and practice of spatial dislocation. At the same time, this article has certain limitations. It has not studied the long-term trend of the spatial dislocation of tourism economy in Jiangsu Province, and only selected the data of 2019 for research. It is worth studying to observe the trend of spatial dislocation through long-term data.

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ARTICLE

The Relationship between Public Service Efficiency of Government and Residential Political Trust in Hong Kong

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ABSTRACT

Hong Kong has a long history with its high efficiency and clean and self-disciplined government. Within the past over 20 years, different social development trend has occurred in Hong Kong. The article observed the relationship between political trust from residence and public service efficiency of government in Hong Kong from 1992 to 2015 and found that the value of public service efficiency has a significant effect on political trust in Hong Kong government, the higher the efficiency of public services, the higher the political trust. The author tried to find the path for the Hong Kong government to improve its public service quality and efficiency after testifying the positive correlation between public service efficiency and residential political trust with empirical analysis.

1. Introduction

Political trust is an important social capital for the development of a society, which depends largely on the social evaluation of the government's public service performance^[1]. This attitude of trust is also dynamic and will run through the process of the dynamic operation of public policy^[2]. In urban politics, the government's capacity and level of public service are mainly reflected

in the efficiency of public service. Hong Kong is a typical urban democratic society of people's livelihood. The population mainly gathers in urban areas with high living density, which is the foundation of Hong Kong's political uniqueness. Due to the social system and market economy of Hong Kong and the great achievements of Hong Kong economy in the second half of the last century, Hong Kong society is a developed urban area with high degree

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of modernization. In regions with such characteristics, the public service of the government is relatively quick, efficient and accurate to affect the daily life of residents in the region. Correspondingly, Hong Kong residents will make a political trust judgment on the government based on the efficiency of public services to a large extent.

Whether before or after the handover, Hong Kong has always adopted an executive-led political system. The transparent, rule-by-law and efficient Hong Kong government is impressive, among which the government's public service efficiency is one of the key expressions. The Hong Kong government's efficient public services play a particularly important role in maintaining social stability and economic prosperity^[3]. In general, increased public spending leads to higher taxes in the region. Hong Kong has a relatively light tax burden internationally, which has a lot to do with the high efficiency of government spending on public services. The Hong Kong government's fiscal policy favors efficiency first^[4]. The government has gradually increased its fiscal expenditure on education, health care and social welfare, thus enhancing the social security of Hong Kong residents. In such an overall affluent and open social environment, residents' political trust in the political system largely depends on the public service efficiency of the government.

During this period after the return to the motherland, Hong Kong's social development showed a different trend. Although Hong Kong society is still dominated by administrative system, the government still faces a thorny problem of social and political trust while providing efficient public services. Under the basic law, Hong Kong residents' political trust in the Hong Kong government determines Hong Kong's continued prosperity and stable development. Hong Kong's social structure is dominated by the urban middle class. This class of people is very interested in the public services of the city government and the political activities derived therefrom. The public services provided by city government are generally highly relevant to the needs of local residents. Such services require the active participation of local residents and rely on residents' timely feedback on their demand for public services. If the local population has a high degree of trust in the political system of the society, they will be very actively involved in the decision-making process of the government's public services, which will have a very positive effect on improving the efficiency of government public services. Hong Kong has a high population density and most residents live in concentrated communities. Therefore, in this case, the higher degree of residents' political trust, the stronger the interaction

between their participation in the system and the decision of the government to provide public services, and the higher the efficiency of the government's public services. As Hong Kong's population continues to grow, residents are demanding more from the government's efficiency in public services. It is of great theoretical and practical significance to study the relationship between the Hong Kong government's level of public goods supply and residents' political trust in the Hong Kong government over the years. This paper attempts to analyze the relationship between governmental public service and residential political trust in Hong Kong and put forward corresponding policy recommendations.

2. Research Hypothesis

Hong Kong has been implementing different economic and social systems from the mainland. The government has not invested a large amount of financial funds into economic development, but the market players bear the responsibility for this part of development. Such a form of government can better avoid the "spillover effect" caused by a large amount of financial investment into economic development, so that it can be better invested in the job of public service. Under the closed urban economic environment, the residents' political trust should be based on the recognition of the government's public service efficiency. Therefore, it has become a valuable proposition to study the relationship between the public service efficiency of Hong Kong government and the political trust of residents. Based on the above analysis, it is reasonable to assume that there is a positive correlation between the Hong Kong government's public service efficiency and residents' political trust, that is, the higher the ratio of the former, the higher the residents' political trust to the government.

In order to objectively evaluate the efficiency of government public services, Data Envelopment Analysis (DEA) will be adopted to measure the efficiency of public services. The specific DEA calculation method will be explained in the third part of this article. First, by comparing the political trust level of Hong Kong residents from 1992 to 2015 with the trend line of public service efficiency of Hong Kong government, we can find that the two lines show a high degree of similarity in the trend (Figure 1). Again, the similarity of the two trends can be observed from the scatter diagram fitting of the two values (Figure 2). This provides the basis for quantitative analysis of the correlation between the two.

Data source: annual survey of Hong Kong government statistics (1993-2016), survey of people's political trust in the Hong Kong SAR government by the University of

Hong Kong (1992-2015).

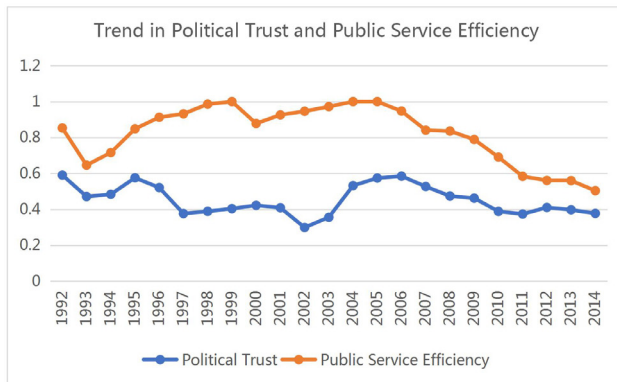


Figure 1. Trends in Hong Kong's socio-political trust and efficiency of government public services

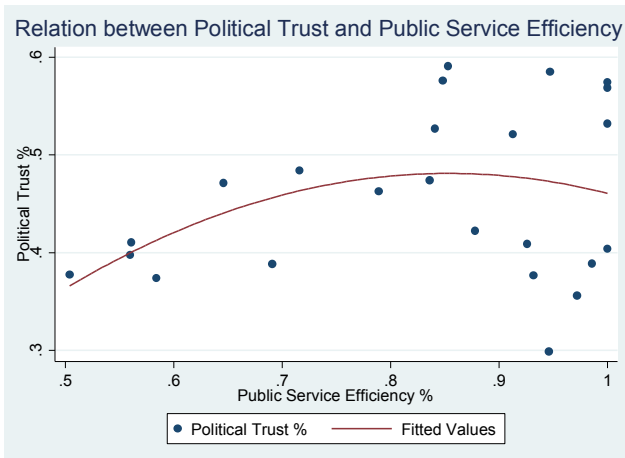


Figure 2. The scatter diagram of Hong Kong's socio-political trust and government's public service efficiency

Research on this topic generally focuses on the relationship between the efficiency of public service expenditure and the government's responsibility for social development^[5]. In this way, there will naturally be studies to explore ways to evaluate public trust in government through government performance^[6]. Residents' political trust will also reduce the cost of government governance reversely. On the relationship between government performance and political trust, the effect of government policy implementation largely determines people's political trust. Similarly, the low efficiency of public services and policy errors will create a sense of political distrust among residents^[7]. The contradiction between the rapid economic development and the adjustment of interest distribution, the quality of public management and the public demand for public service products, etc., can easily cause the public's trust crisis to the government. The paradoxical starting point of political trust has been gradually shifted from economic growth to the provision

of public goods^[8,9]. The efficiency of government governance has become a source of political trust for the increasingly affluent inhabitants of the region. Of course, governance efficiency is closely related to government governance structure, governance behavior and results^[10]. Therefore, to a large extent, government performance determines the level of political trust of residents. A government with poor performance cannot win the trust of citizens. Political trust has different levels of content, and the measurement of government performance is a very complex and macro issue, covering both the political level and the economic and social level. As Hong Kong has experienced a long period of colonial history and a long period of rapid economic growth, it has become one of the developed regions. Residents' satisfaction with the former British government of Hong Kong is basically built on the level of administrative service efficiency and guarantee of the rule of law. Even though Hong Kong society has shown a lot of problems in terms of political trust after its return, some of them are even quite fierce. However, these problems of political culture basically originate from Hong Kong residents' attachment to efficient public services and higher living standards in the region. It is precisely at this point that the views of Hong Kong residents tend to be acquired by seeking a relatively independent administrative environment, rather than deliberately seeking help from the central government. The Hong Kong government's public service input and output to a large extent have the nature of market service or a more obvious "customer-oriented" government value orientation^[11]. The link between the well-being of Hong Kong residents and the level of public goods supply to the Hong Kong government is very strong, and this will quickly affect the relationship between the two. Even in the delivery of public goods such as public housing, the Hong Kong government will seek a balance of efficiency on the basis of fairness^[12]. Therefore, to study Hong Kong's political culture, we should consider the impact of special regional culture and historical traditions on the system.

3. Data Source, Variables and Models

3.1 Data Source

This study examined the correlation between the efficiency of public services of the Hong Kong government from 1992 to 2015 and residents' political trust in the Hong Kong government. The dependent variable is the political trust of Hong Kong residents to the government. The data comes from the statistical value of the sampling survey of political trust of Hong Kong

residents to the government of Hong Kong University polling center. The independent variable input and output data of the Hong Kong government's public service expenditure and other control variables are derived from the Hong Kong statistical yearbook (1993-2016) published by the census and statistics department of the Hong Kong SAR government.

3.2 Variables

The dependent variable in this article is the political trust of Hong Kong residents to the Hong Kong government. Political trust data are fairly intuitive statistics. The use of tracking data from local surveys in Hong Kong can reflect the relationship between the government's public service efficiency and residents' political trust relatively truly. In this article, the political trust value of residents from 1992 to 2015 was used as the dependent variable (Ptrust). The higher the value, the higher the political trust of Hong Kong residents to the government. Hong Kong government's public service performance is selected as the independent variable (PSeff) in this article. The Data Envelopment Analysis is used to calculate the input-output efficiency of public expenditure.

Suppose there are n decision units ($j = 1, 2, \dots, N$), each decision unit has the same m input ($I = 1, 2, \dots, M$), each decision unit has the same s output ($r = 1, 2, \dots, S$). X_{ij} represents the i input of the j decision unit, Y_{rj} represents the output of the r term of the j decision unit, and for each decision unit, j can have the following efficiency evaluation index.

Based on linear programming, the efficient convex production frontier boundary is constructed, and the low efficiency decision unit and its efficiency value can be identified. This method has great advantages in dealing with multiple inputs and multiple outputs when they cannot be converted into uniform units. The operation of linear programming can avoid the measurement problems such as simultaneous equations error and equation setting error. In this paper, we use the assumption of constant return on scale to calculate the efficiency from the perspective of output. Considering that Hong Kong is a highly developed modern city and residents' most important concern of the public goods mainly are the education, health care and social welfare about personal development and the interests of the elements, such as used in this article the input variables have education input, welfare, health investment, infrastructure investment, output variables have public roads, the number of students, teachers, social welfare, medical beds, a decision making unit for every year^[13]. The following figure (Figure 3) shows the efficiency value of public

expenditure over the years.

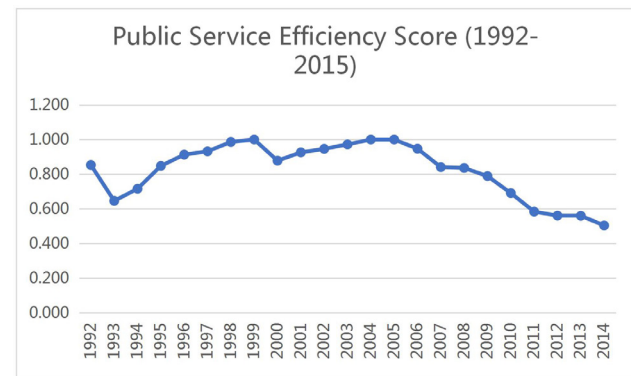


Figure 3. The efficiency trend of Hong Kong's public service expenditure from 1992 to 2015

3.3 Control Variables

The unemployment rate is an extremely important statistic to reflect the social basic level for a city economy with a single economic form like Hong Kong. This paper will control the variable of the unemployment rate (Unem) in the regression model. As mentioned above, the degree of social development and living standard are important indicators for Hong Kong residents to judge the administrative efficiency of the government, because the economic situation will directly affect people's overall judgment of the society in which they live, and thus their satisfaction with the political system. Therefore, this paper will also control the variable of per capita GDP (GDPpc). Hong Kong's economic development has benefited from the reform and opening up of the mainland and the increase of residents' consumption capacity. A large number of mainland consumers go shopping in Hong Kong after policy implementation of independent travel and this phenomenon has made Hong Kong residents change the attitude towards mainland residents. It shows that the scarcity of resources has a great impact on the socio-political trust of Hong Kong residents. Therefore, this article will control the Tourist variable. At the same time, due to the scarcity of resources, the continuous growth of local population will also lead to the shortage of resources and the decrease of the efficiency of government public services, which may lead to negative feelings of residents towards government. So Mid-year demographic variables (Popu) in Hong Kong will also be controlled in the regression model.

Returning to the motherland is a major political change for Hong Kong society. In studying the political trust of Hong Kong residents to the government, this paper puts the time variable of 1997 (D1997) in the quantitative

analysis as the test of robustness. Of course, considering that 1997 is only a total time variable, this paper will further test the effect of the independent variable public service efficiency and the interaction term (PSeff x D1997) in 1997. In addition, PEratio of the Hong Kong government's expenditure on public services as a proportion of the total government expenditure is also a significant indicator variable, so this paper also included it as a control variable into the robustness test model.

3.4 Variable Descriptive Statistics

Table 1 shows the overall statistical description of the data. Residents' political trust in the government is between 30% and 59%, with an average of about 46%. The average input-output efficiency of public services is 0.83, with a maximum of 1 and a minimum of 0.5. Spending on public services averaged 37% of the government's general budget, with a peak of 41% and a minimum of 31%. Between 1992 and 2015, Hong Kong's resident unemployment rate averaged 4.2%, with the highest year at 7.9% and lowest at 1.9%. Per capita GDP is about 190,000 yuan. About 25 million visitors annually visit Hong Kong.

Table 1. Descriptive statistics of variables

Variable	Meaning	Average Value	Standard Deviation	Max	Min
Ptrust	Political Trust	.4571125	.085157	.299	.5908
PSeff	Efficiency Score	.83	.161	.50	1
Unem	Unemployment	.0422083	.0169038	.019	.079
GDPpc	GDP per capita	196824.8	71521.18	112119	316635
Popu	Population	6718925	414507.6	5800500	7305700
Tourist	Visitors to HK	2.50e+07	1.69e+07	8010524	6.08e+07

3.5 Model

This paper conducts quantitative regression model analysis of data from 1992 to 2015 in Hong Kong. The regression model is as follows:

$$Y_t = \beta_0 + \beta_1 * X_t + \beta_z * CV_t + \varepsilon_t$$

Among them, Y_t represents the dependent variable, namely the trust value of residents to the Hong Kong government; X_t represents the independent variable. In this study, government public service efficiency (PSeff) was used. CV represents other control variables that may affect Y . This paper controls the unemployment rate (Unem),

GDP per capita (GDPpc), population (Popu) in that year (Tourist).

The empirical results. In this paper, least square estimation is used as regression analysis method and robust standard deviation is used. Table 2 shows the results of the regression analysis.

Table 2. Model regression results

	(1)	(2)	(3)	(4)
Variables	OSL 1	OSL 2	Tobit 1	Tobit 2
PSeff	0.396*** (0.128)	0.430*** (0.107)	0.405*** (0.117)	0.433*** (0.0862)
Unem	-4.026*** (0.973)	-4.456*** (0.941)	-4.224*** (1.046)	-4.608*** (0.886)
GDPpc	1.55e-06*** (3.97e-07)	1.99e-06*** (5.67e-07)	1.52e-06*** (3.69e-07)	1.95e-06*** (4.76e-07)
Popu	-9.98e-08 (7.20e-08)	4.20e-08 (8.40e-08)	-9.32e-08 (6.73e-08)	5.01e-08 (7.18e-08)
Tourist	-3.53e-09 (2.27e-09)	-4.32e-09 (2.81e-09)	-3.47e-09 (2.02e-09)	-4.19e-09* (2.29e-09)
PEratio		0.940** (0.442)		0.933** (0.360)
PSeff×D1997		0.155 (0.207)		0.166 (0.170)
D1997		-0.270 (0.186)		-0.283* (0.154)
Constant	0.752* (0.372)	-0.513 (0.482)	0.713* (0.353)	-0.555 (0.404)
Observations	24	24	24	24
R-squared	0.770	0.882		

Note:

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

From the results of model 1, it can be seen that the value of public service efficiency has a significant effect on people's trust in Hong Kong government ($\beta = 0.396$;

$p_value < 0.01$). In other words, the higher the efficiency of public services, the higher the citizen's political trust in the Hong Kong government. When the Hong Kong government increases the efficiency level of public services by 1%, residents' trust in the government increases by 0.396%. Therefore, the above hypothesis is verified. The input-output efficiency of the government in public services such as education, health care and social welfare will directly affect residents' political trust in the government.

Considering the time attribute of data, the interaction term ($PSeff \times D1997$) of the public service efficiency of the time-dummy variable and independent variable $D1997$ was added in model 2 as the robustness test. In 1997, this important time point of Hong Kong's return did not have a significant impact on residents' trust in the Hong Kong government. The estimated value of model 2 coefficient is consistent with model 1, and the result is quite robust. Considering the limited trust range of dependent variables, the Tobit regression model is also applied as the robustness test, and the interaction terms of $D1997$ and $PSeff \times D1997$ are also put into the Tobit regression analysis. The results are consistent with ordinary least squares estimation. In particular, the interaction term between the independent variable and 1997 is always not significant in the regression model. Although 1997 was the time of Hong Kong's return to the motherland, the efficiency of public services has always played an important role in Hong Kong residents' political trust in the Hong Kong government. In addition, the results of the control variable also met expectations, and the coefficient of unemployment rate was significantly negative, reflecting that the higher the unemployment rate, the lower people's trust in the government. With each 1 per cent increase in unemployment, trust in government will fall by 4-4.6 per cent. The coefficient of per capita GDP is significantly positive, indicating that the higher per capita GDP level is, the higher people's trust in the government will be.

4. Conclusion

(1) With the rapid pace of China's urbanization in recent years, urban society has gradually changed from an immigrant society to a collection of various interest groups. The issue of political trust in urban governance is extremely important. Political institutions and political actors need to maintain social harmony in the formulation of policies and political practices and prevent social contradictions from accumulating and deteriorating^[14]. It has been 20 years since the return of Hong Kong to the motherland. The central government is very determined to

maintain Hong Kong's long-term prosperity and stability. However, in the light of the international economic and political trends, Hong Kong's aura in the original advantageous fields has faded, the young generation has encountered great challenges in employment, resettlement and other aspects, and Hong Kong society even faces an unprecedented risk of being torn apart. In particular, the "occupy central" incident in the summer of 2014, the rejection of the central government's proposal on Hong Kong's political reform by the legislative council in 2015, and the swearing-in of the new legislative council in 2016 forced people to think about various difficult problems in perfecting Hong Kong's constitutional development in the new stage, in order to maintain Hong Kong's sustained prosperity and stability. What's more, the more radical and disturbing trend of Hong Kong independence is brewing and fermenting in Hong Kong society, making it more and more important to solve the problem of political trust in Hong Kong society. In the new historical period and the new social context, the Hong Kong SAR government has a special political responsibility in social public services, economic restructuring and development, public participation and youth policy.

(2) Cities play an important role in the cultivation and development of civil society. It is easier for city dwellers to get involved in political campaigns about the government's public services^[15]. There are certainly studies that suggest that social participation, as a manifestation of civic sexuality, can generate political trust^[16]. Three months after taking office, the new SAR government, with Mrs Lam as its chief executive, delivered its first policy address, which put forward the idea of paying more attention to people's livelihood. Under the concept of administration, the government's work in its public service can be combined with the development of deliberative democracy mechanism. The former President of Hong Kong's legislative council, Tsang Yok-sing, has also proposed to the government the idea of improving the public participation mechanism. Given the new background of constitutional development, the consultative democratic mechanism related to public services is bound to contribute to the further development of Hong Kong society. Hong Kong people have complex and even contradictory feelings about the system. They may distrust the system on the one hand, but they are accustomed to solving problems through the system on the other hand. Therefore, the SAR government should pay more attention to the relationship between residents' participation in social movements and the cultivation of political trust^[17]. Hong Kong's good social security and civic quality have been one of the main reasons

why mainland tourists are willing to travel in large numbers. In Hong Kong's previous political system, "strong administration-led, efficient civil service system, consulting system" has its advantages. It is closely related to Hong Kong's ability to achieve such prosperity while maintaining social stability at the same time. The establishment of Hong Kong's efficient, clean and neutral civil service system is commendable in the context of Chinese political and cultural background. The new government should continue to strengthen Hong Kong's institutional advantages in these aspects.

(3) Strengthen regional cooperation and extend the public service space. As the population continues to grow, resources, especially in areas such as education and medical care, become increasingly scarce and it is increasingly difficult to improve the efficiency of public services in Hong Kong. Therefore, the government needs to turn to the demand-oriented public supply mode to win greater recognition from residents^[18,19]. The central government proposed in the National People's Congress and the Chinese people's political consultative conference that we should vigorously develop the Guangdong-Hong Kong-Macao greater bay area. The Hong Kong government should take the opportunity to expand the scope of public services, strengthen coordination with other governments in the greater bay area, and strive for greater public service space for Hong Kong^[20]. Hong Kong's rising medical and pension costs have long restricted the health and mental status of the elderly and the sick. Even though the government has increased the investment of higher education and the investment of scientific and technological research and development fund, the high cost of land, entrepreneurship and technology transformation has made it impossible for Hong Kong to complete the construction of scientific and technological innovation center independently and give play to the high internationalization advantage of Hong Kong science and technology education. Therefore, it is important that the Hong Kong government with the aid of a great opportunity for the construction of the bay area of Guangdong, the government and the surrounding area cooperative medical and health innovation, science and technology education and other public goods supply mechanism, the entry and exit, tax reform, the respect such as social security policy, borrowed from the pearl river delta region space and manpower advantage, to further improve the Hong Kong government public service ability and the input and output efficiency.

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ARTICLE

Economic Growth, Industrialization, Trade, Electricity Production and Carbon Dioxide Emissions: Evidence from Ghana

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ABSTRACT

The study scrutinized correlation between electricity production, trade, economic growth, industrialization and carbon dioxide emissions in Ghana. Our study disaggregated trade into export and import to spell out distinctive and individual variable contribution to emissions in Ghana. In an attempt to investigate, the study used time-series data set of World Development Indicators from 1971 to 2014. By means of Autoregressive Distributed Lag (ARDL) cointegrating technique, study established that variables are co-integrated and have long-run equilibrium relationship. Results of long-term effect of explanatory variables on carbon dioxide emissions indicated that 1% each increase of economic growth and industrialization, will cause an increase of emissions by 16.9% and 79% individually while each increase of 1% of electricity production, trade exports, trade imports, will cause a decrease in carbon dioxide emissions by 80.3%, 27.7% and 4.1% correspondingly. In the pursuit of carbon emissions' mitigation and achievement of Sustainable Development Goal (SDG) 13, Ghana need to increase electricity production and trade exports.

1. Introduction

Greenhouse gas (GHG) emissions have increased all over the world^[1]. GHG emissions consist of pollutants such as Carbon dioxide (CO₂), Nitrous oxide (N₂O), Methane (CH₄), and Fluorinated gases (F-gases). Carbon dioxide emission is considered as the greater determinant of greenhouse gases all over the world, which accounts for more than 60% of the biosphere emissions^[2-4]. Ghana economy slowed down from 3.9% in 2015 to 3.3% 2016

based on government implementation of International Monetary Fund (IMF) policy on fiscal and monetary discipline of the Extended Credit Facility. However, Ghana economic growth is projected to increase to 7.1% and 8.0% in 2017 and 2018 respectively^[5] provided the government of Ghana can restore its electricity supply. This projected growth in GDP call for high increase of electricity production to meet demand, which is also expected to contribute towards the carbon emission level^[6,7]. According to^[8] to the United National

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Framework Convention on Climate Change, Ghana contributes 33.66 million tons (Mt) CO₂-equivalent (CO₂e) to the universal greenhouse emissions.^[9] indicates that energy sector of Ghana contributes 25% to the worldwide anthropogenic CO₂ emissions. Even-though Ghana compared to the global average is not considered as one of the high emitters of CO₂ in Africa and the World as a whole.^[8] further stated that carbon emissions in Ghana have increased significantly over the years and still expected to grow over the coming years.

As Ghana is gearing towards industrialization policy of one district one factory, increase in economic development, electricity availability have become critical to achieve the expected growth needed. Since every sector within the economy, whether social or economic requires electricity, government have to balance its energy portfolio to meet the challenges associated with the industrialization and development^[10-13]. Ghana electricity supply coverage as at 2014 stands as 78.3% of the entire country. It is positive in terms of electricity distribution compare to 23.88% in 1990^[14]. This means that in order to meet the 2030 agenda for sustainable development, electricity will play a critical role^[15,16]. Another key issue of concern is the trade impact on carbon emission. Ghana for some time now has attracted considerable trade inflow and outflow which in turn increase economic activities across the country. According to World Integrated Trade Solution (2016), Ghana is ranked at 64th position as the largest export economy to the world. In the year 2016, Ghana export value was around a tune of \$10.5Billion while import value \$11Billion with a negative trade balance of \$508Million. However, little work has been done^[17-19] on the impact of trade both import and export on Ghana's emissions level.

The study aimed to investigate the causal relationship between the variables in Ghana and also to find each variable contribution to emissions in Ghana. It is common to link industrialization, economic growth, electricity production and trade to CO₂ emissions. The importance of this paper could be seen from the contributions it makes to the existing body of knowledge by disaggregating trade into exports and imports of goods and services to explicate the distinct and to find out how trade exports, and imports of goods and services contribute to carbon dioxide emissions level in Ghana individually. The study will serve as an important policy guide to government in Ghana.

The study categorized the remaining discussions into sections with literature review in section 2, materials and methods in section 3, results and discussion in section 4, while the conclusion is in section 5.

2. Literature Review

A lot of studies have shown positive relationship between industrialization, electricity consumption, economic growth, trade and carbon emissions^[20-22] whiles^[23] empirical study also found negative relationship between the variables. Some of the scholars' findings indicated one-way directional association from energy depletion to economic evolution^[22,24]. Others also found the causality running from energy consumption to CO₂^[25] whiles^[21,26,27], found the causality running from economic growth to CO₂. Subsequent studies found bidirectional nexus between the variables^[20,28].

Study of 31 developing countries applied dynamic panel threshold framework^[29]. Study findings attest to other researchers' findings that economic growth contributes to CO₂ emissions in these countries. However, economic growth has a negative effect on CO₂ emissions, particularly when the growth is low but economic growth, however, exhibits a positive effect when growth is high. To buttress findings of study results affirmed the view that economic growth causes carbon dioxide emissions and affects positively the energy intensity of a country whiles examining both direct and indirect effect of urban growth on energy concentration in China^{[29][30]}. Similarly, also investigated the causal dynamics of emissions, energy use and output in six emerging states in Africa^[31]. Results inveterate presence of long-run effect of carbon emissions and economic growth on energy consumption in Ghana whiles economic growth is seen as the positive driving force of energy consumption of countries such as South Africa, Ghana and Kenya. Unidirectional causality was found to run from economic growth to carbon dioxide emissions of countries like Nigeria, Senegal and Egypt. Study using ridge regression to find empirical relationship between carbon dioxide emissions, imports, exports and population in China for the period 1985 to 2006^[32]. The study found an increasing trend in carbon emissions caused by exports. The study brought into being that import increase causes carbon emissions reduction in China.

Conducted a study to find association between carbon stock, electricity production, and consumption. Expending ARDL model and data set from 1971 to 2012, the study found bidirectional causality from electricity production, hydroelectric sources to carbon emissions and vice-versa^[33]. This means that electricity production and consumption increases carbon dioxide emissions in Ghana. Also explored the correlation among energy, economic development, emissions, trade and urban growth in newly industrialized countries. The results of the study

showed that there is no long-term relationship between the variables. Nevertheless, the results of the study show a one-way relationship between economic development and global trade to CO₂ emissions in short-run^[23].

In the same disposition, unidirectional relationship was found running from economic growth to energy consumption, from trade openness to economic growth, from urbanization to economic growth, and from trade openness to urbanization in the short run. Investigated how the relationship exists in Turkey for the period 1960-2005^[34]. The study was conducted using bounds' cointegrating test. The findings are that carbon emissions, energy consumption and foreign trade have effects on income in Turkey in the long run. Therefore, to ensure economic development, Turkey should strive to reduce the carbon emissions through the adoption of macroeconomic policies.

2.1 Economic Growth

Economic growth and ecological pollution nexus has been researched globally by so many researchers^[30,31,35-41]. Some of the findings showed that economic growth causes environmental pollution^[3, 29-31, 42, 43] whiles' others hold the contrary view^[44-48].

2.2 Industrialization

It assumed that as the industrial activity level of country increases, all things been equal, it also increases energy usage^[49]. Study by^[50] to find the effect of industrialization and urbanization on CO₂ in 20 African countries from 1980 to 2013. Findings indicates that the effects of the two variables are classified as direct and indirect. The study found both industrialization and urbanization to have a direct negative effect to the environment of the countries. However, the study also found both variables to have an indirect positive effect on environment. That is, at a certain point in time industrialization will reduce the environmental degradation by swarming over the direct effect.

2.3 Trade

Some of the recent studies found a trade relationship with carbon dioxide emissions level to be positive^[36,51] whiles' others found the relationship to be negative^[23,52]. In contrast, other findings are inconclusive^[19,53]. Most of the studies aggregate exports and import as trade and failed to find their individual essential contribution to emissions^[23, 52, 54-56]. Different words are used by other researchers to mean the same as trade such as foreign trade or trade openness.

2.4 Electricity Production

Electricity is considered as one of the key determinants of any country's economic growth and development. Electricity plays a crucial and indispensable role in our life in terms of cooking, heating, lighting and powering of industries' machines. For sometimes now Ghana electricity supply has been unreliable. The three primary electricity generation mixes in Ghana are hydro, thermal and renewable. The first two, thermal and hydro as at 2016 contributed 56.94% and 42.84% individually to Ghana's electricity generation synthesis whiles renewables contributed 0.22%^[57]. Electricity production in Ghana over the period from 2006 to 2014 has increased by 53.77%, from 8,430 GWh to 12,963 GWh relatively^[58]. As at 2016, the total electricity produced for distribution was around 13,700 GWh as against 11,692 in 2015 and 13,071 GWh in 2014; i.e. 2,008 GWh (about 17%) more than in 2015 and 629 GWh (about 5%) more than in 2014^[57].

2.5 Carbon Dioxide Emissions

Lately, carbon dioxide emissions and its relation to other variables have conventionally received greater attention from researchers^[59-61]. Diverse findings were found that support the view of the relationship of CO₂ with other variables to be positive^[62-66], negative^[67] and neutral^[68-70].

3. Materials and Methods

Even-though^[33] attempted to explore the causal relationship between carbon dioxide emission and electricity production using ARDL regression analysis in Ghana. This study added industrialization and trade to the vital variable sets which are utilized in most topical research work^[33, 71, 72]. The study further disaggregate trade into imports and exports in the nexus. The whole idea is meant to find their contribution independently to carbon emissions in Ghana. To test for the correlation between economic growth, industrialization, electricity production, trade import, trade export and carbon dioxide emissions in Ghana, the study applied econometric model framework. Our study followed recent studies methodology^[33, 73, 74] used by other researchers in both developed and developing countries such as Ghana. All variables were recorded based on their natural logarithm. This phenomenon is common in econometric analysis.

3.1 Data and Variable Definitions

In attempt to investigate the nexus between economic

growth, industrialization, power production, trade imports, trade exports and carbon dioxide emissions in Ghana, our study made use of time series data set from 1971 to 2014. Using Autoregressive Distributed Lag (ARDL) model, data set was obtained from World Development Indicators. The variables used as explanatory variables include; GDP-Gross Domestic Product per capita (current US \$) as proxy of economic growth, IND-Industry, value added (% of GDP) as proxy of Industrialization, IMP-Import of goods and services (% of GDP), XP-Export of goods and services (% of GDP), EP-Electricity production from hydroelectric sources (% of total) and CO₂-Carbon dioxide emissions (metric tons per capita) as the dependent variable.

3.2 Econometric Methods

Empirical model ARDL developed by^[75] is extensively used by many researchers due to its desirable features. One of the key features of ARDL use is its ability to accommodate both stationary and non-stationary data set series in a regression which hitherto was impossible in other approaches such as Johansen's modeling technique. The adoption of ARDL is because the method is applicable whether or not the variables are integrated in the same order. That means that, analysis of data set can be performed whether some of the variables under study are integrated at level I (0), first order, I (1) or

even fractionally integrated. Additionally, ARDL offers unbiased long-run approximations and useable statistical values (i.e. t-statistics) when some of the predictors to the model are endogenous. ARDL allows distinctive lag-lengths to be used in the same model with unlike variables. ARDL techniques help in derivation of the dynamic unrestricted error correction model which intends also to help in determination of both the short and long term without losing any relevant data. To determine the long-run nexus between electricity production, trade, economic growth, industrialization and carbon dioxide in Ghana, the study used unrestricted error correction OLS estimation technique.

4. Results and Discussion

4.1 Model Specification

To determine the long-run elasticities estimate between carbon emissions, economic progress, industrialization, trade imports, trade exports and electricity production in Ghana can be expressed in a linear function as:

$$CO_2 = f(EP_t, IMP_t, XP_t, GDP_t, IND_t) \quad (1)$$

That is, EP, IMP, XP, GDP and IND represent electricity production, trade imports, trade exports, economic growth and industrialization respectively. To reduce multiplicative relationship to an additive one requires the need to take the natural-log of the variables in equation (1). The transformation to the variable in

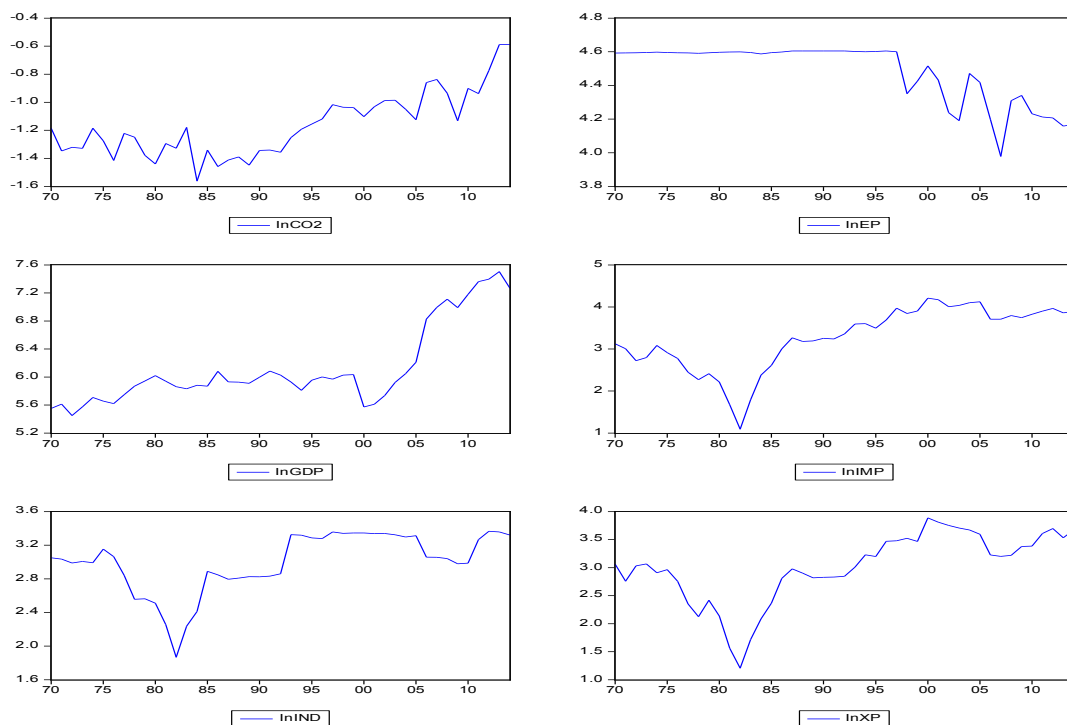


Figure 1: Trend analysis of the variables

natural logarithms is meant to ensure that study variables have a more stable data variance, and therefore, our Log-log linear relationship between carbon dioxide emission, electricity production, trade imports, trade exports, economic growth and industrialization is expressed as follows:

$$\log CO2_t = \alpha + \varpi_p \log EP_t + \lambda_j \log IMP_t + \sigma_k \log XP_t + \psi_L \log GDP_t + \nu_q \log IND_t + \varepsilon_t \quad (2)$$

where α is the constant, $\varpi_p, \lambda_j, \sigma_k, \psi_L$ and ν_q are the coefficient of EP, IMP, XP, GDP and IND respectively. ε_t also represent the white noise of the analysis. The trend of the study variables are shown in Figure 1.

4.2 Descriptive Analysis

The kurtosis results in Table 1 exhibited leptokurtic distribution for all variables. Skewness test results clearly shows that CO2 and GDP display a positive skewness (long-right tail) while EC, EP, IMP, XP and IND exhibited a negative skewness (long-left tail). Table 1 result of Jarque-Bera (JB) test statistic shows that the null concept that the series are normally distributed cannot be accepted at 5% p-value for all the variables except CO2. Even though most of the variables data were found not to be normally distributed, we went ahead to conduct the analysis since the test is not sensitive to normality.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis	JB test	Prob.
CO2	-1.166	0.227	-1.562	-0.589	0.681	3.027	3.478	0.176
EP	4.480	0.175	3.978	4.605	-1.151	3.010	9.935	0.007
IMP	3.265	0.740	1.093	4.208	-0.908	3.292	6.348	0.042
XP	3.005	0.624	1.205	3.888	-0.931	3.495	6.965	0.031
GDP	6.123	0.567	5.449	7.504	1.284	3.317	12.571	0.002
IND	2.997	0.353	1.867	3.365	-1.145	4.071	11.990	0.003

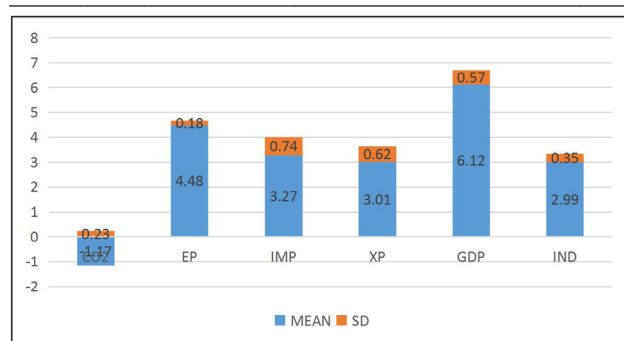


Figure 2: Diagram showing Descriptive Analysis

Figure 2 explains the means and the amount of variability (i.e. standard deviation) of the analysis. Analysis in Figure 2 shows that economic growth (GDP) gave the mean of 6.12, which then becomes the critical variable in Ghana. Notwithstanding that, our standard deviation depicted in Figure 2 exposed imports of goods and services as most volatile variable with highest deviation of 0.74 followed by exports of goods and services of 0.62 in Ghana.

4.3 Unit Root Test

Analysis in Table 2 provides the fundamental test prior to determination of cointegrating relationship between the variables. To test for stationary and non-stationary of the variables, the study applied Augmented Dickey-Fuller (ADF), Philips and Perron (PP) unit root test to execute this task. Nonetheless, time-series data such as ours most of the time produces non-stationary results at the level. The analysis outcomes confirmed this assumption in Table 2, which shows that datasets are non-stationary at the level for both ADF and PP. However, data become stationary at first difference. Hence, accept null proposition at level that unit root exist for entire variables. Hence, the study rejected the null theory of the presence of unit root of the variables in their first difference.

Table 2: Unit root test

	ADF Level	ADF 1st Diff.	PP Level	PP 1st Diff.
Intercept				
CO2	0.12(0.96)	-9.65(0.00)	-0.54(0.87)	-10.79(0.00)
EP	0.94(0.99)	-8.49(0.00)	-1.61(0.47)	-8.99(0.00)
IMP	-1.41(0.57)	-5.37(0.00)	-0.96(0.76)	-4.62(0.00)
XP	-1.42(0.56)	-5.07(0.00)	-1.23(0.65)	-5.04(0.00)
GDP	-0.06(0.95)	-5.25(0.00)	-0.06(0.95)	-5.25(0.00)
IND	-1.41(0.57)	-5.41(0.00)	-1.63(0.46)	-5.30(0.00)
Intercept and Trend				
CO2	-3.29(0.08)	-9.87(0.00)	-3.15(0.11)	-27.42(0.00)
EP	-1.27(0.88)	-9.03(0.00)	-3.63(0.14)	-10.38(0.00)
IMP	-2.63(0.27)	-5.29(0.00)	-2.09(0.54)	-4.56(0.00)
XP	-2.29(0.43)	-5.02(0.00)	-2.26(0.45)	-4.98(0.00)
GDP	-1.23(0.89)	-5.27(0.00)	-1.36(0.86)	-5.23(0.00)
IND	-2.06(0.55)	-5.37(0.00)	-2.25(0.45)	-5.26(0.00)

Note: Augmented Dickey-Fuller (ADF), Philips and Perron (PP)

4.4 ARDL Co-integration analysis

To test for cointegrating among the variables, the study used ARDL bounds testing. The use of ARDL cointegrating technique is to test for the long –run equilibrium relationship between the variables under discussions. Akaike information criterion (AIC) was used to select the optimal model for the bounds' test based on its superior power for data, which is small compared to another lag length criterion^[76]. Results provided by AIC is considered as efficient and consistent compared to another criterion. The optimal model provided ARDL (1, 0, 2, 1, 2, 0) as depicted in Figure 3. The study then applied ARDL bounds test to determine both lower (I0) and upper bounds (I1) in order to compare it to the F-statistic value. Drawing from Table 3, results indicates that our F-statistic value of 3.90 is greater than the critical values of the upper bound at 10%, and 5%. This means that cointegration exists among the variables at 10% and 5%. Therefore, the null hypothesis of no cointegration between CO2, EP, IMP, XP, GDP and IND cannot be accepted. However, at 2.5% and 1%, our test is inconclusive since our F-statistic falls between the lower and upper bounds.

Table 3: Bounds test for co-integrating relation

T-Statistic	Value	K
F-Statistic	3.90	5
Bounds Critical Value		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

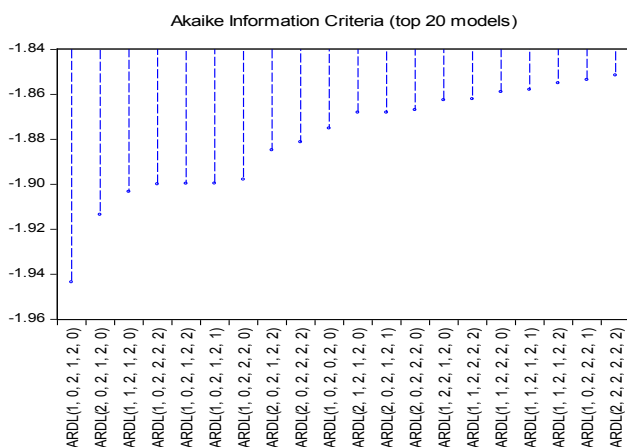


Figure 3: ARDL model selection using akaike information criterion

4.5 Vector Error Correction Model

Having satisfied the pre-condition of ARDL bounds test approach, the study then followed the work of^[77] to estimate the Vector Error Correction Model (VECM) is expressed as:

$$(1-L) \begin{bmatrix} CO2_t \\ EP_t \\ IMP_t \\ XP_t \\ GDP_t \\ IND_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{i=1}^m (1-L) \begin{bmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14} \\ \beta_{21}\beta_{22}\beta_{23}\beta_{24} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64} \end{bmatrix} \times \begin{bmatrix} CO2_{t-i} \\ EP_{t-i} \\ IMP_{t-i} \\ XP_{t-i} \\ GDP_{t-i} \\ IND_{t-i} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix}$$

Where (1-L) epitomizes the change operator, m is the lags, ECT_{t-1} denote the error correction term meant for long-run integration. The α 's, β 's and γ 's represents the parameters whiles ε_t 's are the white noises. With regards to Table 4, which presents the results of the short and long run estimates of the ARDL model shows the speed of adjustment [ECT (-1)= -0.873, P=0.000] which makes the residue from our model to be negative but significant at 5% level. Hence, giving the model speed of adjustment towards equilibrium at 87.3%. This gives a clear indication of long-run equilibrium relationship from EP, IMP, XP, GDP and IND to CO2. The long-run equilibrium relationship was undertaken using F-tests based on null hypothesis of no cointegration between carbon dioxide emissions, electricity production, import of goods and services, export of goods and services, economic growth and industrialization [$H_0 : \varpi_p = \lambda_j = \sigma_k = \psi_L = \nu_q = 0$], with an alternative hypothesis of cointegration between CO2, EP, IMP, XP, GDP and IND [$H_1 : \varpi_p \neq \lambda_j \neq \sigma_k \neq \psi_L = \nu_q \neq 0$]. Wald test technique discoveries in Table 4 shows a rejection of the null hypothesis that, independent variables (i.e. EP, IMP, XP, GDP and IND) combined cannot influence CO2 increase in the short-term. Subsequent findings also revealed that individual predictor with the exception of GDP can influence CO2 in the short-run. However, in the long run, EP, XP, GDP and IND were found to be significant and therefore, can influence the dependent variable.

4.6 Diagnostic Test

The next analysis is to perform key diagnostic test such as the stability test, heteroskedasticity test, serial correlation test, normality test and Ramsey RESET test. The performance of these tests is to ensure that the model is robust. To authenticate our VECM model robustness, the study performed further test to ensure that there is no serial correlation in the residuals, residuals are not heteroscedastic, residuals are normally distributed and no

Table 4: Results of the short and long run estimates of the ARDL Model (Dependent Variable: CO2)

Variable	Coefficient	Standard Error	t-Statistic	Prob.
ECT(-1)	-0.873	0.140	-6.235	0.000*
Long-run Coefficients				
EP	-0.803	0.170	-4.727	0.000*
IMP	-0.041	0.087	-0.473	0.639
XP	-0.277	0.135	-2.056	0.048*
GDP	0.169	0.045	3.738	0.001*
IND	0.790	0.167	4.722	0.000*
C	0.019	1.022	0.019	0.985
Diagnostic test				
Heteroskedasticity:				
F-Statistics	1.040	Prob. F(2,38) 0.363	2.128	0.345
Serial Correlation:				
F-Statistics	0.527	Prob. F(2,29) 0.596	1..509	0.470
Ramsey RESET test:				
F-Statistics	0.222	(1,30) 0.640	0.472	0.640
Jarque-Bera test	0.534			0.766
Short-run equilibrium relationship				
Wald test	F-Statistics	Prob.	Chi-square	Prob.
EP	9.428	0.001*	18.856	0.000*
IMP	3.974	0.033*	7.948	0.019*
XP	4.223	0.027*	8.445	0.015*
GDP	1.247	0.306	2.495	0.287
IND	3.785	0.038*	7.569	0.023*
Jointly	4.005	0.003*	40.055	0.000*

Note: *denotes significance level at 5%.

variable is omitted from the analysis. Outcomes in Table 4 indicates a P-value of $0.77 > 0.05$ of the residual analysis, and therefore, we accept the null hypothesis that residuals are normally distributed. Our test results provided undoubted view of non-existence of heteroscedastic effect in the model. Hence, accept the null assumption of

no heteroscedastic effect in the model as shown by the P-value $0.35 > 0.05$. The study serial correlation using Breuch-Godfrey Serial Correlation Lagrange Multiplier test also accepted the null proposition that there is no serial correlation and that our P-Value >0.05 . Stability test of the model was performed through the use of CUSUM

and CUSUM of squares. Our results in Figure 4 and Figure 5 shows that in both CUSUM and CUSUM of squares lines fall within the 5% significance level which confirmed the VAR stability conditions of the model. The Ramsey RESET test on the other hand, also projected that no variable is omitted in the model and therefore, the null hypothesis of no omitted variables in the model cannot be rejected at 5% significance level and that no misspecifications in the model.

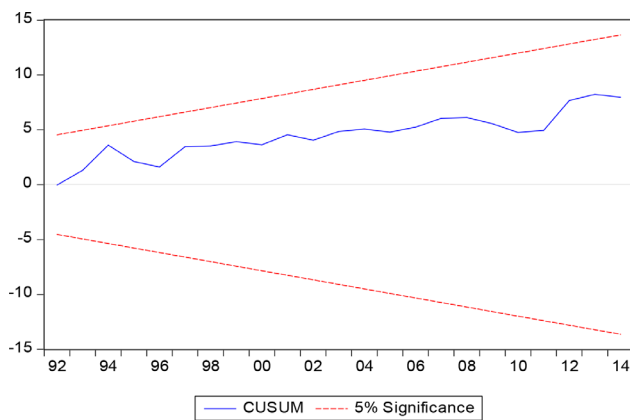


Figure 4: CUSUM

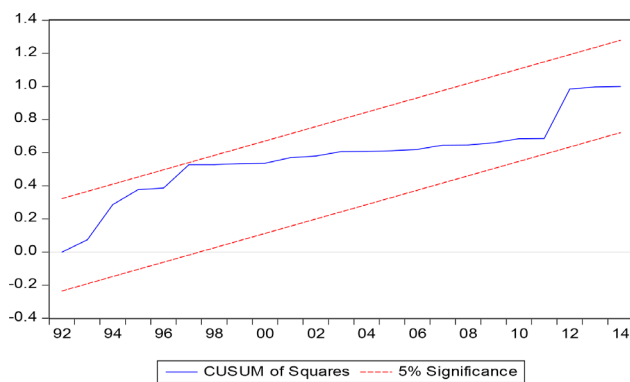


Figure 5: CUSUM of squared

4.7 Granger-Causality

The next stage involved the test of causality to define the cause-effect relationship between the variables. Results in Table 4 indicated that there is long-term relationship between the variables at 5% significance level. However, the application of ARDL to determine the long-run relationship failed to address the issue of cause and effect for the variable among themselves, particularly with regards to CO₂. It is against this background that our study went further to employ Granger-causation based on VECM to assess direction of causality among variables. Granger causality test in Table 5 shows that the null hypothesis that INCO₂ does not Granger cause INEP does not hold at 5% significance level. Therefore, reject

the hypothesis and accept the alternative that INCO₂ causes INEP in Ghana. The test also revealed that imports and exports are the two volatile variables in Ghana as disclosed in our descriptive analysis diagram (i.e. Figure 2), which shows that both causes carbon dioxide emissions (CO₂) and industrialization in Ghana. Table 5 disclosed unidirectional causality runs from INCO₂→INEP, INIMP→INCO₂, INXP→INCO₂, INIMP→ININD and INXP→ININD at 5% significance level. The use of (→) denotes the direction of causality.

Table 5: Granger causality relationship

Null Hypothesis	Obs.	F-Statistic	Prob.
INEP does not Granger Cause INCO ₂	43	1.48442	0.2395
INCO ₂ does not Granger Cause INEP		3.90700	0.0286**
INGDP does not Granger Cause INCO ₂	43	1.24672	0.2989
INCO ₂ does not Granger Cause INGDP		0.15422	0.8576
INIMP does not Granger Cause INCO ₂	43	3.81590	0.0309**
INCO ₂ does not Granger Cause INIMP		1.21570	0.3078
ININD does not Granger Cause INCO ₂	43	2.31635	0.1124
INCO ₂ does not Granger Cause ININD		1.39498	0.2602
INXP does not Granger Cause INCO ₂	43	3.24637	0.0499**
INCO ₂ does not Granger Cause INXP		2.47634	0.0975
INGDP does not Granger Cause INEP	43	1.13192	0.3330
INEP does not Granger Cause INGDP		1.21046	0.3093
INIMP does not Granger Cause INEP	43	3.00490	0.0614
INEP does not Granger Cause INIMP		0.86311	0.4300
ININD does not Granger Cause INEP	43	1.32791	0.2770
INEP does not Granger Cause ININD		0.41707	0.6620
INXP does not Granger Cause INEP	43	2.73846	0.0774
INEP does not Granger Cause INXP		0.86542	0.4290
INIMP does not Granger Cause INGDP	43	0.67698	0.5142
INGDP does not Granger Cause INIMP		0.33938	0.7143
ININD does not Granger Cause INGDP	43	0.27036	0.7646
INGDP does not Granger Cause ININD		0.34656	0.7093
INXP does not Granger Cause INGDP	43	0.88922	0.4194
INGDP does not Granger Cause INXP		0.69573	0.5050
ININD does not Granger Cause INIMP	43	0.40427	0.6703
INIMP does not Granger Cause ININD		5.07777	0.0111**
INXP does not Granger Cause INIMP	43	3.07134	0.0580
INIMP does not Granger Cause INXP		2.32720	0.1113
INXP does not Granger Cause ININD	43	4.70297	0.0150**
ININD does not Granger Cause INXP		0.23137	0.7946

**denotes rejection of the null hypothesis @ 5% significance level.

4.8 Generalized Impulse Response

The performance of Granger-Causality is to test the direction of causality among series but has its own drawbacks of not probing into how variables, particularly the dependent variable (CO₂) will respond to random innovations in other variables. Application of generalized impulse-response analysis is meant to overcome the inherent problem that comes after the current period and also to prevent orthogonal problems associated with out of sample Granger-causality tests. That is, the Generalized Impulse Response analysis is meant to find the responsiveness of the outcome variable (i.e. CO₂) in the VAR when there is a random innovation of the individual predictor. Figures 6 shows a skyward increase or decrease of the predictor's one standard deviation shock to CO₂ emissions in Ghana from time period 5 to 10. From period 1 to 5, all the variables showed a rising trend shock to CO₂. However, response of INCO₂ to INEP, INXP and ININD shows a gradual decline from period 5 to 10. Nonetheless, same cannot be said about the response of INCO₂ to INGDP and INIMP, that is, constant upward trends are envisaged. Results of the Generalized Impulse Response function encapsulated the response of INCO₂ to an innovation of the explanatory variables. Findings in Figure

6 showed that within 10-period horizon, the response of INCO₂ to INEP and; INCO₂ to ININD is that one standard deviation shock given to INEP and ININD caused a decrease in INCO₂ is insignificant. In contrast, the response of INCO₂ to INXP over the period is significant but decreasing steadily. Moreover, response of INCO₂ to INGDP and INCO₂ to INIMP shows a sign of continual trend and significance within the 10-period horizon. The findings from Generalized Impulse Response Function indicated that when one dispersion shot is imputed in economic advancement (GDP), and trade imports caused a constant increase in carbon dioxide emissions in Ghana. However, when one standard deviation is introduced into exports, it causes an increase in carbon emissions with a downward trend. Contrary, when a standard deviation plan is calculated in industrialization and electricity production leads to a decrease in carbon dioxide emissions in Ghana by a constant trend over time.

5. Conclusions

Empirical investigation was performed to find the causal relationship between electricity production, economic growth and CO₂ by including industrialization and splitting trade into imports and exports of goods and ser-

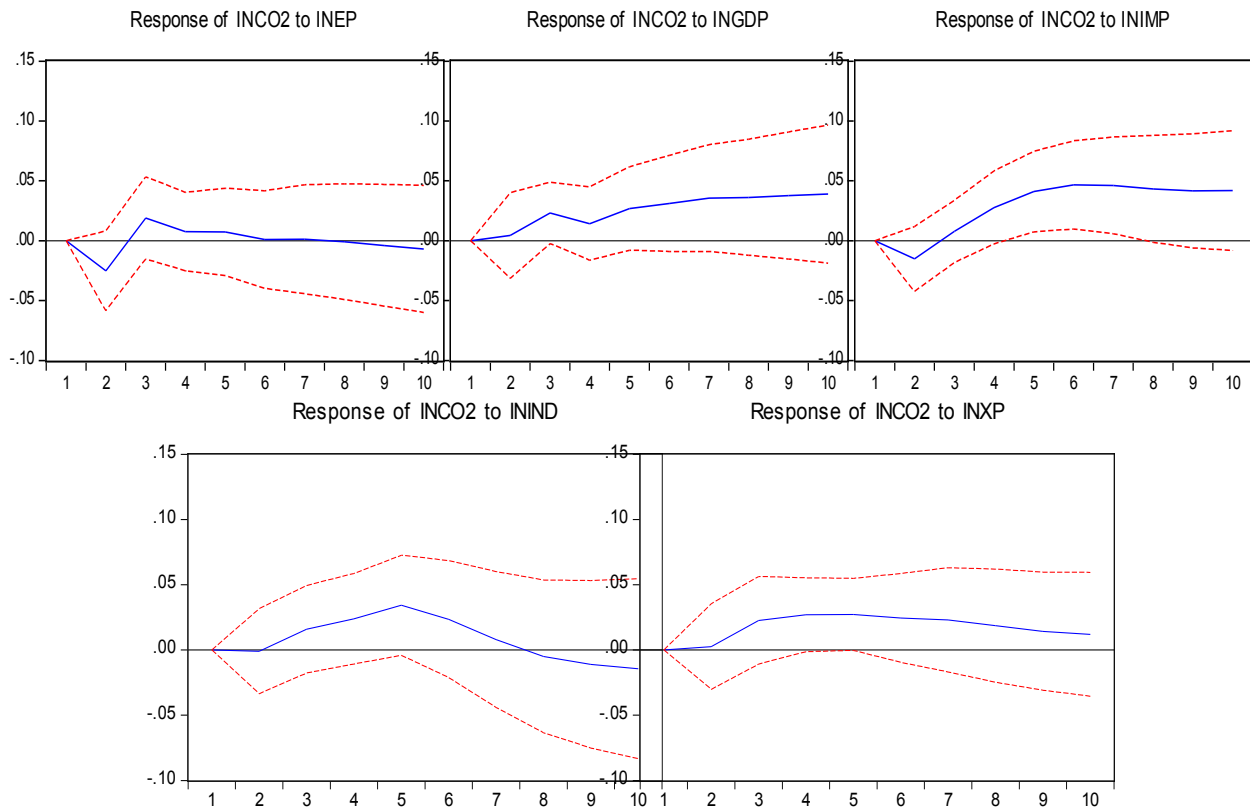


Figure 6: Response of carbon dioxide to other variables

vices to find the potential determinants of CO₂ emissions in Ghana. The study with regards to Ghana perspective has become relevant and significant as Ghana is gearing towards industrialization of one district one factory policy, increase in economic growth, increase in trade and development, electricity availability has become critical to achieve the expected growth and development needed. The realization of the outlined policies is assumed to increase the emissions level across the country. Therefore, the need to find the potential marginal effects or contribution to the emissions levels for policy guidance in Ghana. Using Autoregressive Distributed Lag (ARDL) model and time series data set for the period 1970 to 2014 from World Development Indicators. Subsequent to the determination of cointegrating relationship, the study employed Augmented Dickey-Fuller (ADF) and Philips and Perron (PP) test to check the stationary and non-stationary of the data set. Findings indicate that variables are stationary at their first difference. Evidence from Bounds test shows long-run cointegrating exist between the dependent variable and explanatory variables. Results of bounds test further explains the joint effect of the predictors to the dependent variable (CO₂) at constant will increase CO₂ emissions by 1.9% in Ghana. Wald test shows that, all the variables are significant at 5% in the short-term except for GDP.

Nonetheless, the long-term effect on the variables on CO₂ emissions indicated that GDP and IND increase of 1% each will cause an increase of CO₂ emissions in Ghana by 16.9% and 79% individually. Nevertheless, one-percent change in the magnitude of electricity production, trade exports and trade import causes a decrease in proportionate change of CO₂ emissions by 80.3%, 27.7% and 4.1% correspondingly. The study findings made it clear that increase in electricity production, trade exports and trade imports in Ghana is a plus in reducing CO₂ emissions. The reverse is the case with an increase in GDP, and IND. Granger causality test found uni-directional causality runs from CO₂→EP, IMP→CO₂, XP→CO₂, IMP→IND and XP→IND. On this score one can deduce that Ghana economy is trade-led economy. Therefore, implementation of good policy to improve trade (i.e. both import and export) taking into account the environmental effect will help Ghana to achieve its industrial economy policy. The findings from Generalized Impulse Response Function indicated that one standard deviation shot is charged in economic growth (GDP), and trade imports (IMP) caused a constant increase in carbon dioxide (CO₂) emissions in Ghana. However, one standard deviation shot is imputed in trade exports (XP) causes an increase in carbon dioxide (CO₂) emissions at a declining trend. Contrary, when one

standard deviation shot is imputed in industrialization (IND), and electricity production (EP) causes a decrease in carbon dioxide (CO₂) emissions in Ghana at constant trend over the time period.

Our results support the findings of ^[33] that uni-directional causality runs from carbon dioxide emissions to electricity production. Similarly, fallouts of the study support the findings of ^[23, 32] that uni-directional causality runs from both imports and exports to carbon dioxide emissions. However, our findings support ^[78] study but hold a contrary view to the findings of ^[32] to the effect of exports in the long term. In the pursuit of carbon emissions' mitigation and achievement of Sustainable Development Goal (SDG) 13, Ghana need to increase electricity production and trade exports.

Conflict of Interest :No conflict of interest to be declared by all authors of the study.

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