The relationship between food production and political stance based on canonical correlation analysis and empirical mode decomposition: taking the U.S.-DPRK relations as an example

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ABSTRACT

The U.S. policy toward North Korea has always been an issue of great concern and research focus. According to the grain production data of North Korea, and combined with perspectives from experts of China, the United States and South Korea, this paper tries to make a tentative judgment of the hawk/dove tendency of the five U.S. Presidents’ remarks on North Korea from 1989 to 2019. The results show that: (1) The hawkish tendency in the presidents’ attitudes has a certain relationship with North Korea’s grain production. However, dove tendency is related to grain yield and its fluctuation rate, and the impact of the rate on the dove stance is even greater than the impact of production. (2) When North Korea’s grain production increases, the presidents’ stance on North Korea’s policy tends to be tough; but when its grain production decreases, the presidents’ attitudes towards North Korea will become relatively moderate. (3) The fluctuation rate of grain production in North Korea will affect the dove tendency of the presidents. Their stance will be more moderate if the rate decrease. But if the rate rises, the moderation of the statements will retreat.

Introduction

In the study of international relations, the decision-making system of a country’s foreign policy is like a mysterious ‘black box’. Opening this ‘black box’ to explore the secrets of decision-making has always been a strong attraction. Black boxes, also known as flight data recorders and cockpit voice recorders, store information about planes. They can assist in the investigation of aircraft accidents by giving critical information. Decision support system (DSS) is a kind of software-based system, which mainly helps the country or organisation to take decisions based on the information gathered from the several fields of information system involved in organisational business processes like processing and automation system. Generally speaking, the major powers are the leading roles in the international political arena, and their foreign policy has a great impact on the development of international relations. Since the end of the cold war, the United States, as the only superpower in the world, its foreign policy trend can be an important indicator for judging the world political situation. Therefore, it is of great significance to study the factors that influence the foreign policy of the United States. Moreover, it will play a positive role in resolving international conflicts and promoting international cooperation and a better understanding of the sustainability of foreign policies of the United States as well.

A country’s foreign policy is often demonstrated through three levels: (1) intentional policy, (2) declaratory policy, (3) operational policy, in which the declaratory policy is used to define the set of statements that present in a state to consider nuclear weapons. Meanwhile, the operational policy is used to describe the high-level guide of operational decisions and development strategies of the country. The first level reflects the real interests and goals of the government. The second level is the policy elaborated by government officials. The third level is actually adopted by the government (Amstutz 1999). Of course, there are often inconsistencies between the government’s real intentions, external announcements and actual actions from
the perspective of practice. However, when we want to grasp a country’s foreign policy, the public announcement of government officials is still a very important indicator. The president is the head of state and executive leader of the United States, who is the core of the foreign policy decision-making circle (Amos et al. 1981). Therefore, the president’s public statement is one of the most important bases for understanding American foreign policy.

Among the foreign relations of the United States, the relationship between the United States and North Korea is of great particularity: North Korea is the only country in the world that has been refused recognition by the United States since its establishment, and even the war between it and the United States has not really ended. It has been 70 years since the outbreak of the Korean War. The Korean War was started, when the North Korean Communist army crossed the 38th Parallel and attacked non-Communist South Korea. Fearing that the United States might use North Korea as a base for operations against Manchuria, the People’s Republic of China deployed an army over the Yalu River in secret. The United States has also experienced 13 presidents in power. Successive presidents of the United States have followed a deep-rooted ‘Cold War mentality’ in their policies towards North Korea. The term cold war is nothing by the military tension or political hostility between two countries including threats, propaganda, short of open welfare or other economic sanctions (Morton and Priscilla 2006). However, Different presidents’ stances varied at different times. What factors are influencing the U.S. presidents’ attitudes towards North Korean policy and what are the influencing paths are the main problems that this paper attempts to solve.

Generally speaking, the decision-making process of foreign policy can be analysed through three levels: macro, meso and micro. The macro level analysis mainly takes the international system as its research perspective. Singer thinks that the international system level can help us to examine international relations as a whole (Singer 1961). In view of this, the U.S. policy toward North Korea can be grasped from the macro level of international system changes. For example, the U.S. policy towards North Korea was obviously influenced by the bipolar structure during the cold war. Because North Korea is subordinate to the socialist camp led by the Soviet Union, the United States has always held a hostile attitude towards North Korea. Richard believes that North Korea poses a serious threat to the peace and security of South Korea and the entire Pacific region (Richard 1994). Although the cold war has ended and the bipolar structure has collapsed, the United States still formulates its policy towards North Korea from the perspective of maintaining the hegemonic system. The hegemonic is generally referred to as rule and leadership. While, the hegemony has the ability to shape the international system through non-coercive and coercive means in international relations. Lee examines the U.S. policy toward North Korea at a global level. From the perspective of the United States’ attempt to construct a single hegemonic system and prevent the proliferation of weapons of mass destruction after the cold war, he analyses the relevance between the nuclear issue and the U.S. policy towards North Korea (Lee 1994).

The meso level perspective of foreign policy decision-making includes two dimensions of state and society. (1) From the perspective of state analysis, the state is regarded as a unified rational actor. In decision making, it calculates the benefits and losses of the policy, so as to make the most favourable choice (Graham 1969). According to this logic, the U.S. policy toward North Korea is completely based on its own interests and has a clear ‘instrumental’ orientation. Paul Bracken believes that the United States has never had an independent and complete strategy towards North Korea. During the cold war, the U.S. policy toward North Korea served only as a tool to serve the global supremacy contest between the United States and the Soviet Union (Paul 1998). Even after the end of the cold war, the U.S. policy toward North Korea still has an obvious ‘instrumental’ colour. For example, George W. Bush’s North Korea policy serves his big strategic goal of fighting terrorism ‘instrumentally’ (Bruce 2009). (2) The theoretical basis of the social analysis perspective is pluralism, which holds that various social organisations constitute the basis of pluralistic politics. Private clubs, cultural organisations, political parties, trade unions and so on will affect the government’s decision-making (Robert and Bruce 2002). Wang focused on the impact of mainstream think tanks on the U.S. government’s policy-making towards North Korea. He believes that the trump government’s North Korea policy basically reflects the consensus of mainstream think tanks (Wang 2018). Piao also pointed out that the news media consciously or unconsciously intervened in the U.S.-DPRK relations. DPRK is an abbreviated form of Democratic People’s Republic of Korea. It is mainly used to define the foreign relations of North Korea. It is also used to encounter its shape with South Korea and to tie the world communism. Both North and South Korean governments are claimed to sole legitimate government of the whole of Korea. It has even been used in the increasingly fierce propaganda and psychological warfare of hostile countries, and has become an important part of the U.S. decision-making towards North Korea (Piao 2014).
The micro level analysis of foreign-policy decisions is mainly from the perspective of organisation and individual: (1) The organisational perspective emphasises the influence of the operational mechanism of state institutions in decision-making. Kenneth pointed out that the internal structure of a country is one of the keys to understanding war and peace (Kenneth 1954). Under this logic, the U.S. policy toward North Korea is the product of the game, coordination and compromise among its national institutions. For example, starting from revealing the complex political structure of American domestic politics, Im made in-depth research on the contradictions of bureaucratic politics and the relationship between the administrative departments and the Congress, and then made an in-depth study of the U.S. policy towards North Korea (Im 2004). On the other hand, Leon pointed out that the failure of U.S. diplomacy toward North Korea is due to its complicated policy-making process, the decentralisation of executive power, departmental egoism and the weakening mediation capability of the National Security Council (Leon 1998). (2) Personal perspective attaches importance to the individual factors of decision-makers, believing that the decision-maker’s personal psychological cognition, policy philosophy, party political culture and personal emotions will affect the decision-making process (Eugene et al. 2004). For example, Chan believes that labelling North Korea as an ‘axis of evil’ country, to some extent, had influenced the adaptation of a tough policy towards North Korea at the beginning of the Bush administration. He also advocated stopping aid to North Korea and controlling the process of U.S.-DPRK reconciliation (Chan 2001). However, the notion of constructing international cooperation and diplomatic negotiations to solve the nuclear issue, Obama administration had advocated peaceful dialogue with North Korea at the beginning of his term in office (Barack 2007).

By combing the existing studies, we can find that the academia has made a detailed explanation of the factors influencing the U.S. policy decision-making towards North Korea from different analysis levels, but there are still some deficiencies. (1) The existing three levels of analysis mainly focus on the subject of policy-making – the United States, but the relationship between the United States and North Korea is an interactive process. North Korea, the target of the U.S. policy, will also have an impact on the formulation of the policy. However, the academic circles often neglect the factors that play a role in North Korea. (2) In terms of research methods, the vast majority of studies still use qualitative methods, while quantitative studies are rare. (3) Although scholars have analysed the factors that influence the U.S. policy toward North Korea, they have not explained the specific path of these factors influencing the policy. Therefore, this paper intends to take the grain yield of North Korea as a research starting point. Through the methods of canonical correlation analysis and empirical mode decomposition, this paper quantitatively and systematically studies the correlation between North Korea’s grain output and the U.S. presidents’ attitudes towards North Korea after the cold war. Complicated dataset is transformed into a small and finite number of components by using Empirical model decomposition (EMD) and the decomposed components from the orthogonal basis for the original signal completely. The empirical model decomposition is also known as intrinsic mode functions (IMF). Then it reveals the ways of North Korea’s grain production affecting the U.S. policy towards North Korea.

**Model and method**

**Data**

As this paper attempts to clarify the correlation between North Korea’s grain production and the U.S. presidents’ policy statements on North Korea, we should master the relevant data of North Korea’s grain production. Grains are essential because they offer a good supply of carbs, which are essential nutrients. Carbohydrates are a form of sugar that gives organisms the energy they need to function. Grains are high in carbs as well as other essential minerals like vitamins. Moreover, we should assign scientific and reasonable values to the hawk/dove tendency of the U.S. presidents’ attitudes towards the DPRK policy. First of all, this paper uses the ‘North Korea statistics portal’ of the Korean statistics office to collect grain production data of North Korea from 1989 to 2019 (North Korea Statistics Portal 2020). Secondly, when scoring the hawk/dove tendency of the U.S. presidents’ attitudes towards North Korea policy, we search the White House website and the Presidential Library of successive presidents. Then, we comb the public statements of the five presidents (Bush Sr., Clinton, George W. Bush, Obama and Trump) in the 31 years (1989–2019), and forms a compendium of the main points of the U.S. presidents’ attitudes towards the DPRK from 1989 to 2019. After that, ten experts from China, the United States and South Korea were involved in the anonymous scoring on the hawk/dove tendencies in the compendium of key points. Then we obtained the average scores of the experts on the hawk/dove score of the U.S. presidents’ attitudes towards North Korea policy from 1989 to 2019.
**Canonical correlation analysis**

In multivariate statistical analysis, it is often necessary to study the correlation between two groups of random variables. Canonical correlation analysis is to transform the correlation between two groups of random variables into a few pairs of variables. Association among two variables is identified and measured by using canonical correlation analysis. It also identifies the set of orthogonal linear combination and canonical variation among the variables to explain the variability among sets. And these few pairs of variables are unrelated. Its basic idea is to solve two known zero mean random vector groups \(x\) and \(y\). It finds a pair of projection directions \(a\) and \(b\), so that \(u = ax\) and \(v = by\) have the maximum correlation. This correlation is called canonical correlation and \(u\) and \(v\) are typical variables. \(u_1\) and \(v_1\) are the first pair of typical variables. Then, starting from \(u\) and \(v\), we find the second pair of typical variables \(u_2, v_2\), so that they are not related to the first pair of typical variables \(u_1, v_1\). In this way, the correlation feature extraction of \(u\) and \(v\) is finished. The term correlation is the statistical measure, which is used to identify which two variables are going to fluctuate together. It helps us to know how much one variable differs from another variable and it takes values depending on the direction of change. In this way, the correlation analysis between the two groups of vectors \(x\) and \(y\) can be studied by a few pairs of typical variables \(u, v\). A matrix is used to define the relationship between several dimensions, when the population is higher than more random or higher dimension variables is called Covariance matrix. Also, the relationship between every two random variables and entire dimensions is described by using this matrix. The mathematical description is: If there are two groups of random vectors \(x_i\) and \(y_i\), where \(x_i\) and \(y_i\) are \(n\)-dimensional row vectors, then the covariance matrix of \(x\) and \(y\) is:

\[
\text{cov}(x, y) = \begin{bmatrix}
  \text{cov}(x, x) & \text{cov}(x, y) \\
  \text{cov}(y, x) & \text{cov}(y, y)
\end{bmatrix} = 
\begin{bmatrix}
  S_{11} & S_{12} \\
  S_{21} & S_{22}
\end{bmatrix} = S
\]

That is, \(S_{11}\) is the covariance matrix of the first group of variables \(X\), \(S_{22}\) is the covariance matrix of the second set of variables \(Y\), \(S_{12}\) is the covariance matrix between the two groups of variables \(x\) and \(y\). And \(S_{12} = S_{21}\). For two groups of variables \(x\) and \(y\), the linear combination of vector is considered.

\[
\begin{align*}
  u_1 &= ax = a_{11}x_1 + a_{12}x_2 + \ldots + a_{1m}x_m \\
  v_1 &= by = b_{11}y_1 + b_{12}y_2 + \ldots + b_{1m}y_m
\end{align*}
\]

Among them, \(a = (a_{11}, a_{12}, \ldots, a_{1m})\) and \(b = (b_{11}, b_{12}, \ldots, b_{1m})\) are nonzero constant vectors. The coefficient vectors \(a\) and \(b\) are selected to maximise the correlation coefficient.

\[
\rho = \frac{\text{cov}(u_1, v_1)}{\sqrt{\text{var}(u_1)\text{var}(v_1)}}
\]

When considering the standardised random variables \(u_1\) and \(v_1\), among them:

\[
\begin{align*}
  \text{var}(u_1) &= \text{var}(ax) = aS_{11}a' = 1 \\
  \text{var}(v_1) &= \text{var}(by) = bS_{22}b' = 1
\end{align*}
\]

That is: \(\rho = \text{cov}(ax, by) = aS_{12}b'\).

The Lagrange multiplier method is used to find \(a\) and \(b\) to maximise \(\rho\). At this time, \(\rho\) is called the canonical correlation coefficient of typical variables \(u_1, v_1\).

In the significance test of canonical correlation analysis, the statistics were calculated firstly:

\[
Q_i = \left[ n - i - \frac{1}{2}(m + p + 1) \right] \ln \lambda_i \tag{2}
\]

where \(\lambda_i = (1 - \lambda_1) \ldots (1 - \lambda_k)\), \(k\) is the number of eigenvalues greater than zero of matrix \(S_{11}^{-1}S_{12}S_{21}^{-1}S_{22}\).

Under the assumption of \(\sqrt{\lambda_1} = 0, \sqrt{\lambda_2} = 0, \ldots, \sqrt{\lambda_k} = 0\), when the sample size \(n\) is large, the statistic \(Q_i\) approximately obeys the \(\chi^2\) distribution with degree of freedom \((m - i + 1) \times (p - i + 1)\). For a given significance level \(\alpha\), if \(Q_i > \chi^2_{1-m}(m - i + 1) \times (p - i + 1)\), the original hypothesis is negated. It is considered that at least one typical correlation coefficient is not zero. The maximum canonical correlation coefficient is \(\sqrt{\lambda_1} = 0\). It is considered that the \(i\)-th canonical correlation coefficient is significant at level \(\alpha\). In other words, the \(i\)-th pair of typical variables was significantly correlated.

**Empirical mode decomposition**

The empirical mode decomposition (EMD) approach is a novel form of adaptive signal time–frequency processing method that is particularly well suited to nonlinear and non-stationary signal analysis and processing. EMD may stabilise non-stationary data, then use the Hilbert transform to generate a time–spectrogram and a frequency having physical significance. It’s a method for determining the spectrum analysis of the minimum phase response. Meanwhile, an energy signal appears after conducting a standard frequency calculation. The Fourier transform is \(t=0\), and it also creates the phase’s linear delay component. Though the spectrogram represents signal intensity in a visual manner, the wavelet transform is used to depict the signal present at
various times and frequencies. There is no need to specify any basis functions in advance since EMD can execute signal decomposition depending on the time scale properties of the data itself. As a result, EMD has a clear advantage in the processing of non-stationary and non-linear data, as well as the ability to analyse non-linear and non-stationary signal sequences and a high signal-to-noise ratio.

This approach may decompose a complex signal into a finite number of intrinsic mode functions (IMF), each of which contains local characteristic signals from distinct time scales of the original signal. The intrinsic mode function is the oscillatory component of a signal collected after Hilbert-Huang transformation. In order to retain the signal's properties and physical relevance, its intrinsic function must be accurately extracted from the signal. The following two requirements must be met by the deconstructed IMF. The number of extreme points in the IMF must not exceed 1 or be equal to the number of zero-crossing points. Suppose the microseismic signal is $x(t)$, then the EMD can be decomposed into a series of IMF components, which can be expressed as:

$$x(t) = \sum_{i=1}^{a} \text{imf}_i(t) + r(t)$$

Among them, $\text{imf}_i$ represents the $i$-th IMF component. $r(t)$ is the decomposition residual term. The decomposed IMF components are arranged in order of frequency from high to low. In the application of microseismic signal noise reduction, the high frequency IMF component is usually removed as noise, and the remaining IMF component can be reconstructed to achieve denoising.

The EMD algorithm is based on generating smooth envelopes defined by the local maximum and minimum of the sequence and then subtracting the average value of these envelopes from the initial sequence. This requires identifying all local extreme values, and then further connecting these extreme values with cubic splines to generate upper and lower envelopes. Then the average value is calculated based on the two envelopes, and the average value calculated in this way is further subtracted from the initial sequence to obtain the intermediate signal. If there are negative local maxima and positive local minima in the intermediate signal (this criterion is equivalent to whether the above empirical mode decomposition condition is satisfied), it means that this is not an eigenmode function IMF, and it needs to continue to screen. The screening process is to continue to repeat the above steps with the intermediate signal as the new input signal. The screening process usually stops when the residual number contains no more than two extreme values.

In the process of IMF decomposition, the dominance of noise on IMF components is gradually reduced, and the dominance of signals on IMF is continuously strengthened. Therefore, it is necessary to determine the boundary $\text{imf}_k$ between signal and noise among $m$ IMF components. The method to determine the boundary $\text{imf}_k$ is as follows. Firstly, use Equation (4) to calculate the cross-correlation coefficient between the original signal and each IMF component.

$$\frac{\sum_{i=1}^{N} [x(t) - \bar{x}][\text{imf}_i(t) - \bar{\text{imf}}]}{\sqrt{\sum_{i=1}^{N} [x(t) - \bar{x}]^2 \sum_{i=1}^{N} [\text{imf}_i(t) - \bar{\text{imf}}]^2}}$$

In Equation (4), $x = \frac{1}{N} \sum_{i=1}^{N} x(t)$, $\text{imf}_i = \frac{1}{N} \sum_{i=1}^{N} \text{imf}_i(t)$, $x(t)$ represents the original signal, $\text{imf}_i$ represents the $i$-th IMF component, $N$ is the number of sampling points. Secondly, in a series of cross-correlation coefficients obtained by Equation (4), search for the corresponding IMF component when the first cross-correlation coefficient takes a local minimum, and the following IMF component is the boundary between noise and signal, denoted as $\text{imf}_k$, then $\text{imf}_k$ is the modal aliasing component. Finally, the first $k-1$ IMF is filtered as noise, the independent component analysis is performed on the $k$th IMF, and the effective signal is extracted and reconstructed with the remaining IMF to achieve the noise reduction of the microseismic signal.

**Multiple linear regression**

Wavelet transform is an analysis method of signals based on time–frequency. It can characterise signals in time and frequency domains featuring multi resolution. The frequency and time of the signal associated is delivered with the help of wavelet transform. The wavelet transform is also used to make easy application for various fields. After the wavelet transform shifts the basic wavelet by $\tau$, it performs an inner product with the analytic signal at different scales $\alpha$:

$$WF(\alpha, \tau) = \langle f(t), \psi_{\alpha, \tau}(t) \rangle = \frac{1}{\sqrt{\alpha}} \int_{-\infty}^{\infty} \psi^* \left( \frac{t - \tau}{\alpha} \right) dt.$$  

This formula, $\alpha > 0$, which is called the scale factor, is used to expand and contract the basic wavelet $\psi_{\alpha, \tau}(t)$. $\tau$ can reflect the displacement. $\alpha$ and $\tau$ are continuous variables. The continuous wavelet transform is the tool, which is used to deliver the complete representation
of the signal by measuring the scale parameters and translation of the wavelets continuously. Therefore, it is also called continuous wavelet transform.

Complex Morlet wavelet is a single-frequency complex sine-modulated Gaussian wave, and it is also the most commonly used complex-valued wavelet, of which the time–frequency domain has good locality (Li 2014b). The Morlet wavelet is a wavelet, which consists of a complex exponential carrier multiplied by the Gaussian window. The Morelt wavelet is also termed as ‘Gabor wavelet’. Therefore, this kind of wavelet is closely related to vision and hearing of human perception. Therefore, this paper selects a complex Morlet wavelet as the basic wavelet function and calculates it by using matlab2018b. Complex Morlet wavelet can be shown as follows:

\[ \psi(t) = (\pi f_b)^{-0.5} e^{2\pi i f_c t} e^{-t^2/f_b} \tag{6} \]

**Multivariable linear regression**

The parameters representing the grain situation are utilised as independent variables to explain changes in the policy tendency, based on which a multivariable linear regression model is developed to investigate the link between the policy tendency (hawks or doves) and the food situation. Multiple linear regression is a technique for determining the mathematical expression for a general connection between two independent variables \( X \) and dependent variable \( Y \).

\[ y = cx + \epsilon \tag{7} \]

Note \( \epsilon \) represents the constant term and \( c \) is the regression coefficient. Regression co-efficient is nothing but the estimates of unknown parameters to describe association among response and the predictor variables. Meanwhile, in linear regression, the values that multiply the values of predictors are called co-efficient.

**Discussions**

**Empirical mode decomposition of political stance**

As shown in Figure 1, the pigeon index is decomposed into two principal components. The first principal component is similar to the original data and has a strong explanatory degree. The second principal component has a period of about five years, but the range of change gradually decreases.

As shown in Figure 2, the Eagle index is decomposed into three principal components. The explanation of the first principal component of the Eagle Index is the same as that of the Pigeon Index. The second principal component shows a 7-year cyclical trend. The amplitude of this trend at the beginning and the end is relatively large, reflecting the violent fluctuation of the Eagle Index. The third principal component is represented by a relatively stable 12-year cycle, with small amplitude and insignificant changes.

**The relationship between food production and political stance**

In this paper, canonical correlation analysis is used to study the relationship between North Korea’s grain production and the U.S. president’s policy statement towards North Korea. Canonical correlation analysis can determine the relationship between two groups of related variables. By selecting the hawkish index \( y_1 \), dove index \( y_2 \) and North Korea’s grain output \( x_1 \), the president’s statement is made, typical correlation

![Figure 1. Empirical mode decomposition of Pigeon Index.](image1)

![Figure 2. Empirical mode decomposition of Eagle Index.](image2)
The results are as follows:

\[ \begin{align*}
    u_1 &= -0.0683x_1 - 0.0018x_2 \\
    v_1 &= -0.0292y_1 - 0.1037y_2 \\
    u_2 &= -0.1235x_1 + 0.0021x_2 \\
    v_2 &= -0.0840y_1 - 0.0705y_2
\end{align*} \]

The first group of related variables \((u_1, v_1)\) passed the significance test at 5% significance level, and the correlation coefficient was 0.5879. It can be concluded that there is a certain correlation between the grain yield of North Korea and the hawk/dove tendency of the U.S. president's policy towards the DPRK. The president's policy statement is one of the important indicators to understand the country's foreign policy. Foreign policy is affected by both internal and external environments. The external environment includes geographical factors, international interplay factors and international system factors. Among them, the interplay between one country and other countries in politics, military, economy, culture and other aspects is an important factor for this country to decide its foreign policy (Gideon 1998). With the regard of Neo-classical realism, how the state views and treats the external environment needs to analyse the transformation process. Neo-classical realism is considered as one of the most important approaches for international relations. It explains the strategies of individual states, which are different form recurrent patterns of international outcomes while focusing on the interaction between internal dynamic and international system of states. How the external energy, including the domestic factors of other countries, is transformed through the unit (country) level as the intermediary variable (Chi et al. 2020). That is, a country's foreign policy is influenced not only by its domestic politics but also by other countries. In particular, the domestic situation of the target country has an impact. For example, during most time of the cold war, the United States pursued a containment strategy against the Soviet Union and adopted a confrontational policy; however, since Gorbachev launched the 'new thinking' reform, the political changes in the Soviet Union triggered the adjustment of the U.S. policy toward the Soviet Union. President Bush confirmed the end of the period of confrontation between the two countries at the summit of the United States and the Soviet Union in Malta in December 1989. Therefore, grain production, as an important part of North Korea’s domestic politics, will naturally affect the U.S. policy towards the DPRK and the attitudes of the U.S. Presidents towards the DPRK.

After confirming the correlation between the grain yield of North Korea and the hawk/dove tendency of the president of the United States, this paper further analyses the specific relationship between the grain yield and the hawk/dove tendency of the president by using the method of multiple linear regression. Multiple linear regression analysis is to find out the linear relationship between the dependent variable \(y\) and \(P\) independent variables by qualitative analysis. Regression analysis is a proven way of determining which factors have an influence on a certain issue. Regression analysis helps you to accurately establish which elements are most important, which factors may be ignored, and how these factors interact. Bivariate Regression Analysis is a technique for determining the strength of a connection between two variables. Then one or more independent variable factors which significantly affect the change of \(y\) can be found out, and these factors can be used to form a multiple linear regression model.

The grain production, fluctuation rate, hawk/dove score and average score of hawk and dove in North Korea policy statement of the United States are brought into the model.

The conclusions are as follows:

In Table 1, the \(p\) value of grain production in North Korea is less than 0.01, which is highly significant at the significance level of 1%. The hawkish index can better explain the tendency of the presidents’ statement. The hawk index will increase by 0.0115976 for every unit of grain yield increase. It shows that North Korea’s grain production is closely related to the hawkish index of the announcements of the presidents. That is, when North Korea’s grain production rises, the hawkish index also rises, and the U.S. president’s stance towards the DPRK tends to be tougher. This is because food is an important guarantee for North Korea to maintain its regime and ensure its national security. It is also a necessary prerequisite for the development of nuclear weapons. When the grain production of North Korea rises, the problem of food and clothing of the people in North Korea can be improved to a certain extent. The leadership tends to shift more energy to nuclear development and take a more tough policy toward foreign countries when 'internal worries' are alleviated (Kelsey 2020). Under such circumstances, the president of the United States will take a tough policy.

Table 1. Regression coefficient of American hawk index.

| Coefficients | Standard error | t Stat | p-value |
|--------------|----------------|--------|---------|
| Yield        | 0.0115976      | 0.0004928 | 23.54   | 0.000*** |
| Fluctuation rate | 0.3498467  | 0.2809751 | 1.25    | 0.223    |

***, **, and * were significant at 1%, 5% and 10% significance levels, respectively.
statement to show his determination to counter DPRK resolutely. For example, since 2001, North Korea’s grain production has increased in the next four years, the development of nuclear weapons has been put on the agenda of Kim Jong Il’s regime. In early October 2002, U.S. Assistant Secretary of state Kelly visited North Korea and showed ‘strong evidence’ that North Korea developed nuclear weapons secretly. He also said North Korea had acknowledged its uranium enrichment programme (Victor 2003). In this context, the Bush administration of the United States adjusted the relatively moderate policy towards North Korea in the late Clinton administration comprehensively. Instead, the policy of imposing mandatory and military punishment on North Korea is increasingly adopted, which is known as the ‘Hawk engagement’ policy (Bob 2002). In March 2001, shortly after Bush took office, he publicly said that he would not resume negotiations with North Korea soon, and ridiculed South Korean President Kim Dae Jung’s ‘sunshine policy’ of reconciliation with North Korea (The White House 2001). In the following June, George W. Bush comprehensively expounded the new government’s policy towards North Korea. North Korea is defined in the constitution as ‘a dictatorship of people’s democracy’ led by the Workers’ Party of Korea (WPK), which has legal primacy over all other political groups. It said it would try its best to contain North Korea’s nuclear development programme and it reduces North Korea’s military power. After the ‘9.11’ incident (The White House 2002), Bush further linked North Korea with the anti-terrorism war. North Korea, Iran and Iraq were listed as ‘axis of evil’ and ‘countries supporting terrorism’ and they were called ‘threat to world peace’. Judging from the interaction between the United States and North Korea at the beginning of George W. Bush Administration (Selig 2001), the increase of North Korea’s grain production has strengthened the confidence of Kim Jong Il’s regime to develop nuclear weapons and to be tough with the outside world. On the contrary, this has stimulated the return of conservatism in the United States, thus pushing the president to shout in the tone of ‘Hawks’ in North Korea and take a tougher policy.

It can be seen from Table 2 that the dove index stated by the U.S. president is affected by North Korea’s grain production and its fluctuation rate. Both of them passed the P-test at the significance level of more than 5%. Among them, there is a large negative correlation between grain yield and dove index: If the grain yield is reduced by 1 unit, the dove index will increase by 0.0116842. This means that when North Korea’s grain production declines, the U.S. president’s policy stance towards North Korea will become more moderate. This is because the United States is well aware that the food issue is a top priority for North Korea’s social security and stability. When North Korea’s food production drops or even runs short, its government will have to seek help. This is the perfect opportunity for the United States to influence North Korea’s politics and promote its internal changes through aid. An official in the white house once said bluntly: ‘internal revolutions often don’t break out at the most difficult times. It happens when the living environment improves’ (Mike 2002). Therefore, when North Korea’s grain production is reduced, the U.S. presidents tend to use ‘gentle words to comfort’. And through providing different ways of aid, ‘political buy-off’ and ‘peaceful evolution’ were carried out on North Korea. In addition, the perception of North Korea by American leaders is divided into two parts. They made no secret of their antipathy towards the North Korean regime and its leaders, calling them ‘the most dangerous regime’, ‘tyrant’ and ‘devil’ (Balamurugan et al. 2021b). But to the North Korean people, they are willing to provide them with the necessary humanitarian assistance. Moreover, the U.S. Congress will only impose restrictions on economic assistance to hostile countries (Balamurugan et al. 2021a). There are no restrictions on humanitarian aid. It also reduces the obstacles to the presidents’ aid to North Korea and their moderate policy (Gong 2007). For example, the floods in 1995 led to a sharp decline in North Korea’s grain production that year, resulting in a loss of about 900,000 tons of food (Li 2014a). Then the drought in 1996 and 1997 further worsened the already stretched food situation in North Korea. Under such circumstances, President Clinton quickly seized the opportunity to ‘infiltrate’ North Korea and implemented a ‘soft landing’ strategy with obvious dove colour (Venkatraman and Alazab 2013). He announced to start dialogue and consultation with North Korea and lift some economic sanctions (Yong 2003). The relationship between the United States and North Korea also improved to a certain extent in the late Clinton administration.

Table 2 also shows that the fluctuation rate of North Korea’s grain production has a great impact on the dove index of the announcement expressed by the president: The regression results showed that the dove index increased by 0.6288393 for every 1% increase in

| Coefficients | Standard error | t Stat | p-value |
|--------------|----------------|--------|---------|
| Yield        | -0.0116842     | 0.0004468 | -26.15  | 0.000*** |
| Fluctuation rate | 0.6288393 | 0.2547471 | 2.47 | 0.020** |

***, **, and * were significant at 1%, 5% and 10% significance levels, respectively.

**Table 2. Regression coefficient of American dove index.**
grain yield. In other words, if the fluctuation rate of North Korea’s grain production decreases, the U.S. president’s stance will be more moderate. But if the rate increases, the moderate attitude will be reserved. The decline of the rate means that the situation of grain production in North Korea is not optimistic. American presidents tend to use mild language so as to carry out ‘gentle shouting’ and ‘peaceful evolution’. However, the rise in the rate means that North Korea’s grain production is developing in a better direction, and the president is not willing to implement the policy of appeasement to North Korea. This is because U.S. leaders believe that North Korea’s strategic intention is to develop weapons of mass destruction and export missiles. North Korea is currently the world’s most enigmatic and inaccessible country. Pyongyang’s administration, officially known as the Democratic People’s Republic of Korea (DPRK), is led by possibly the most erratic and enigmatic political leader alive. There has never been a significant individual in the early twenty-first century who has been more loathed by Americans. The ultimate goal is to drive the United States out of the Korean Peninsula (Stephen et al. 2008). Therefore, if food production is not optimistic, the United States will conclude that ‘time is on our side’. At this time, promoting moderate policies such as food aid can promote the expansion of the North Korean market, weaken the prestige of its leaders and help the United States achieve greater diplomatic goals (Michael 2007). But if North Korea’s grain production shows signs of improvement, it will continue to work hard to implement its true intentions. Under such circumstances, if the United States blindly ‘appeases’ the DPRK, it will undoubtedly encourage the ambition of the DPRK (Kumar et al. 2020). And even if peaceful means are used, the United States should maintain a tough stance (Wang 2013). So the president is not inclined to be more ‘pleasant’ to North Korea.

But it’s worth noting that the impact of the fluctuation rate of North Korea’s grain production on the dove index of the U.S. president’s statement is greater than that of the grain output on the dove index. This is because the fluctuation rate refers to the increase or decrease of grain output in this year compared with the previous year, which is a percentage; the rise and fall of grain output is the amount of increase or decrease in the current year compared with the previous year. Compared with the rise and fall of output, the rate can better reflect the change of North Korea’s grain output. In particular, the grain situation in North Korea is getting better or worse. Due to the lack of mutual trust between the United States and North Korea for a long time, the United States is full of suspicion and hostility towards North Korea. Therefore, between the tough ‘containment’ and the moderate ‘contact’, the presidents of the United States are more inclined to accept the ‘containment’ policy, and are often cautious in ‘contact’ (Victor and Sue 2020). In view of this, the fluctuation rate that can better reflect the change of grain output is compared with the rise and fall amount. It has more reference value for the U.S. presidents to make a modest statement, and has a greater influence on the dove policy.

Although the situation on the Korean Peninsula has eased to some extent since 2018, after the second summit meeting between the DPRK and the U.S. leaders held in Hanoi in February 2019, the process of reconciliation between the two countries has experienced hardships and setbacks (Mi et al. 2010). After the breakdown of the Hanoi meeting, North Korea soon began to resume the reconstruction of the Sohae launching site and the missile test, which makes the U.S. believed that North Korea hindered the denuclearisation process (Victor 2019). However, North Korea accused the United States of sticking to the red line of ‘no denuclearization, no lifting of sanctions’ and no sincerity of reconciliation (Orjuela et al. 2020). In early 2020, the COVID-19 swept the world. The United States has been greatly impacted, becoming the country with the largest number of confirmed cases and deaths in the world. Trump should not only focus on dealing with the epidemic, but also prepare for the presidential election at the end of the year (Soo 2020). As a result, the variables of the U.S. policy toward North Korea have increased. At the same time, North Korea also faces the prospect of grain production reduction due to the COVID-19 and flood disaster. According to the above research, we can predict the political attitude of the U.S. President (Biden and his successors) to North Korea according to North Korea’s grain output and the its fluctuation, so as to further judge the U.S. policy towards North Korea in the next stage.

Conclusions

This paper analyses the relationship between North Korea’s grain output and the U.S. presidents’ public statements on North Korea from 1989 to 2019 through canonical correlation analysis and multiple linear regression. The conclusions are as follows:

(1). The formation paths of the hawk/dove tendency of the U.S. presidents’ attitudes toward North Korea are different: The hawkish tendency in the statement is only related to the grain yield of North Korea, and the impact of the fluctuation rate of the output on the hawk index is not statistically
significant. In contrast, the dove tendency in the statement is not only related to the grain yield, but also closely related to the fluctuation rate, and the rate has a greater impact on the president’s dove stance.

(2). The increase and decrease of North Korea’s grain production help to predict the attitudes of the U.S. Presidents towards North Korea: When North Korea’s grain production increases, the U.S. president’s attitude towards North Korea will tend to be hawkish, and the policy toward North Korea is easy to be tough. When grain production declines, the U.S. president’s attitude towards North Korea will become relatively dove like, and its policy towards North Korea will be more moderate.

(3). The fluctuation rate of grain production has a greater impact on the dove tendency of the U.S. presidents’ attitudes towards the DPRK: If the rate decreases, the U.S. president’s attitude will be more moderate; the rate rise, the president’s dovish tendencies will be reserved.

(4). The U.S. policy toward North Korea has always been a hot issue in academic research. As the grain production of North Korea can be used as an important indicator to predict the attitude of the U.S. President towards the DPRK, we can judge the development and sustainability of the U.S. policy toward the DPRK according to its grain output, no matter who is the president.

(5). The realisation of regional cooperation in Northeast Asia needs a peaceful and stable regional environment. The U.S. policy toward North Korea plays an important role in this process. Because North Korea’s grain production can be used as an important basis for predicting the U.S. policy toward the DPRK, we can judge the stability and sustainability of regional relations in Northeast Asia, so as to better guide the effective development of trade, investment and other economic activities.

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