

The evolution of sustainability ideas in China from 1949 to 2015, quantified by culturomics

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Abstract

Previous cultural evolutionary analyses have used neutral models as null models to distinguish between the unbiased copying and the biased transmission of cultural traits. Here, we define economic and ecological concepts as cultural traits that constitute a complex system representing sustainability ideas. We analyse the frequency distribution, turnover and innovation rates of 3,713 concepts appearing in China's mainstream newspaper, People's Daily, from 1946 to 2015. Results reveal that (1) economic concepts show a stronger tendency towards random copying than ecological concepts; (2) popular economic ideas experience anti-conformist bias, while ecological ideas experience conformist bias; (3) the differences in popular concept variability indicate that cultural drifts are stronger in disciplinary domains than in cross-disciplinary domains; and (4) the frequency change in popular sustainability ideas also suggests positive selection due to political strategy and governmental behaviour. The study can promote vibrant and resilient ecological knowledge to foster sustainability activities and behaviours.

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Introduction

A core aim of sustainability science is to link sustainability knowledge with actions and behaviours that lead to real sustainability (Clark and Dickson 2003; Clark 2007; Miller 2018). While over 30 years has passed since the Brundtland report (UN-WCED, 1987), unsustainable behaviours and collective actions

have resulted in ever-worsening environmental challenges, and practical actions are urgently needed. Recent studies on sustainability knowledge and concepts have found that despite incremental progress in studies in sustainability science, the role of sustainability knowledge and concepts in affecting societal change remains uncertain (Apetrei et al. 2021). Cross-disciplinary cultural evolutionary studies (Cavalli-Sforza and Feldman 1981; Boyd and Richerson 1985; Neiman 1995; Shennan 2003; Richerson and Boyd 2005; Mesoudi 2011) have used concepts, tools and methods from evolutionary biology to interpret massive quantitative data by exploring the interaction between gene cultures to explain human behaviour and have succeeded in offering insights into behaviour-culture-societal change (Kandler and Crema 2019; Prentiss 2019). Based on Darwin’s (1981) analogies between language and species evolution, examining word creation and extinction in the language system (Petersen et al. 2012; Ruck et al. 2017) could unravel the underlying forces and changing patterns of cultural evolution by analysing language transmission (Pagel et al. 2007; Newberry et al. 2017; Pagel et al. 2019).

In the last two decades, the random copying model of the neutral theory of population genetics (Crow and Kimura 1970; Kimura 1983) has been used as a null hypothesis and model in testing value-neutral cultural traits (Bentley and Shennan 2003; Hahn and Bentley 2003; Bentley et al. 2007; Reali and Griffiths 2010; Leroi et al 2020) and cultural drift and selection forces. This model has already been applied in various cultural domains to track social change, such as baby names, dog breeds, music, commonly used words and public media in popular culture (Hahn and Bentley 2003; Herzog et al. 2004; Bentley 2008; Dediu et al. 2012; Acerbi and Bentley 2014; Sindi and Dale 2016), academic terminology, technological patents, cryptocurrency and colour terms in academic culture (Bentley et al. 2004; Acerbi and Bentley 2014; ElBahrawy 2017; Carrignon et al. 2019; Brand et al. 2019). However, this approach has not been applied to discover the cultural dynamics of sustainability.

Concepts, cultural behaviours, or artefacts in cultural evolution are regarded as cultural replicators (Evans 2012). Cultural selection is most likely to operate on the semantic dimension of language organization (Biber and Gray 2016). Concepts are ‘simple’ noun phrases composed of a determiner and head noun that represent human recognition and construction of the world (Altmann et al. 2011). Different concepts may occupy a specific *niche*, which may influence the frequency change and dynamics of concepts related to social identity (Gillespie 1998). Therefore, economic concepts reflect the fundamental activities of human survival and the essence of the Anthropocene. Ecological concepts emphasize well-being and sustainable development. The conflict between economic growth and ecological preservation has long existed in both developed and developing countries. Through an evolutionary analysis of ecological and economic concepts, we attempt to answer the following research questions (RQ): RQ 1, How have ecological and economic concepts changed throughout China’s different development phases? RQ 2, What changes have occurred in mainstream sustainability ideas? RQ 3, What is the underlying evolutionary force of sustainability ideas? and RQ4, what approaches to policy and management might better transmit sustainability ideas to advance the role of sustainability?

In this paper, we track the dynamics of sustainable ideas for the past 70 years, covering the duration from the foundation of China to the attainment of the world’s second-largest economy. We use culturomics analysis to detect drift and selection in ecological and economic concept usage in China. The concepts are drawn from the *People’s Daily*, which is the largest newspaper group and mainstream media in China. The aim of this study is to determine the interactions among governmental policy and strategy, public opinion, and personal decisions at the population level in dealing with the trade-off among ecological restoration, environmental protection and economic growth.

Materials and Methods

Public media, as a transmitter (Cavalli-Sforza and Feldman 1981), mirrors the shift in public attention and preferences in this conflict and accelerates the transmission and diffusion process of these concepts. Assuming that no concept is intrinsically more valuable than another and envisioning the copying of concepts as ‘replication’ and the invention of new concepts as ‘mutation’, this process is analogous to the population genetics mechanism of random drift (Wright 1931; Crow and Kimura 1970; Hansen 2018), while transmis-

sion biases would indicate cultural selection (Cavalli-Sforza and Feldman 1981; Boyd and Richerson 1985; Richerson and Boyd 2005). The neutral model in cultural evolution assumes that copying is undirected, without biases or different ‘fitnesses’ of the words being replicated. If random copying is used as the null hypothesis of the neutral model, frequencies should exhibit a right-skewed distribution in which a few traits are very popular, and most traits remain rare (Acerbi and Bentley 2014; Sindi and Dale 2016; Carrignon et al. 2019). In contrast to random copying, frequency-dependent copying of independent decisions generates an exponential decay distribution, or conformist bias, copying popular traits or rare traits, and an irregular ‘humped’ distribution in the case of frequency trimming, or anti-conformist bias, avoiding the copying of popular traits or rare traits (Mesoudi and Lycett 2009). The latter becomes indistinguishable from random copying when trimming is applied to common traits (Michel et al. 2011). As another neutral model, the turnover rate model can differentiate the selection type and determine when cultural transmission is biased based on the turnover profile (Acerbi and Bentley 2014). In addition, the neutral model predicts that random sampling is the only source of change in variant frequencies over time. The diachronic dynamics of individual cultural variants can be analysed by using the value of NV/v (Carrignon et al. 2019). The variability in the value NV/v approaching 1 might be identified as variants copying randomly and experiencing a neutral evolutionary force.

Public media has a close relationship with public opinion and governmental actions. A change in concepts might account for news attention being a ‘threshold event’ or ‘tipping point’ (Hansen 2018). In this analysis, concepts were taken from the *People’s Daily* of China. This newspaper provides information on the policies and viewpoints of China and is also the best representation of the Chinese ecological philosophy and sociocultural tradition. A total of 3713 concepts and their frequency data were retrieved from the BLCU Corpus Center (BCC), representing a time span of 70 years, from 1946 to 2015 (Xun et al. 2016). The BCC corpus is a large, full-text retrieval corpus with approximately 15 billion words, including 2 billion words from the *People’s Daily*. The query function in diachronic retrieval provided data from the newspaper for the years 1946-2015. A Boolean query of ‘Ecological + Noun’ AND ‘Noun + Ecology’ AND ‘Economic + Noun’ AND ‘Noun + Economy’, where N has the same function as Noun, was applied to all years from 1946 to 2015 (Zhang 2021).

In this paper, we use both the progeny distribution and the turnover rate models. The progeny distribution model focuses on frequency and probability and, in our case, is defined as the cumulative fraction. In the calculation of the cumulative fraction of concept frequency, we choose a single-year segment to calculate the absolute frequency and cumulative fraction of all ecological and economic concepts in that year. The relative frequency is calculated by the ratio of the actual frequency of the concept to the total number of phrases in the year.

We define cumulative fraction (P_{ci}) as

$$P_{ci} = \sum_{i=1}^i P_i \quad (1)$$

where p_i is the frequency of a concept in a certain year,

$$p_i = n_i/N \quad (2)$$

where n_i is the frequency of a certain concept, and N is the sum of all frequencies of all concepts.

Turnover rate model: We follow previous work by Evans and Giometto (2011) in defining turnover z in the top y chart. The list of the y most popular concepts is defined as the sum of the number of concepts existing in the top chart plus the number of new concepts entering the top chart at the same time step. The y list in this research varies from 14 to 35 (depending on the sufficiency of data).

The turnover can be described by generic function (3),

$$z = ay^b \quad (3)$$

where b is the power and 0.86 in the judgment criteria of the neutral model (Evans and Giometto 2011).

Concept mutation: Any concepts that did not appear in the previous year are considered new concepts, and the total number of phrases is retrieved from BCC (Xun et al. 2016). The calculation begins in 1975, with a time span of 5 years (data before 1975 are insufficient).

Concept variability: Phrases with structures such as ‘noun + ecology’, ‘ecological + noun’, ‘noun + economic’, ‘economic + noun’ (semantically parallel to Chinese concepts) were retrieved from the BNC (British National Corpus) corpus. To use BNC concept results as a reference for the international recognition of sustainability ideas, the most popular concepts in ecological and economic domains were selected based on their total frequency across 70 years. Choosing the 10 most popular concepts in each category (the above four conceptual structures) resulted in a total of 40 concepts. Actual frequency was taken as the first criterion and overlapping concepts as the second, with the research list finally narrowing to 5 concepts for each category for a total of 20. The values of NV/v of these 20 concepts were then calculated. The variance V of concepts was calculated as

$$V_n = \sum_n \frac{(v-v)^2}{n-1} (4)$$

where v is the average frequency of the concepts and uses variance V ,

$$V = \frac{v(1-v)}{N} (5)$$

where v is the relative frequency of the variant as a fraction of N , the total sum of variant copies per generation. According to Bentley (2008), given a small v , when $v \ll 1$, rearranging eq. (5), $v(1-v) \approx v$ indicates that $NV/v \approx 1$.

Results

Different evolutionary forces and processes underlying economic and ecological concepts diachronically change

The diachronic frequency dynamics and cumulative frequency distribution of words in the mainstream newspaper, *People’s Daily*, show that the popularity of China’s economic activities has increased rapidly, with an average annual word frequency of 1,689 occurrences in the past 70 years but with considerable changes (Fig. 1a). From 1946 to 1953, the frequency of economic words showed a rapid growth trend, with an average annual growth of 4,211 occurrences. In the mid-1950s, the frequency of word use decreased by 1,156 occurrences a year. After the late 1960s, the frequency of word use increased sharply, by 5,045 occurrences a year, until it reached a peak in 1992 and then decreased rapidly, with word frequency decreasing by 4,345 occurrences a year. It rose rapidly again after 2005, increasing by 5,447 occurrences a year and reaching a second peak (163,847 occurrences) in 2010. In the early stage, the growth rate of ecological word frequency was very slow (Fig. 1b). In the 30 years after 1946, the average word frequency increased only three occurrences a year. Between 1978 and the 1990s, it increased slowly, at a rate of 120 occurrences a year. Entering the 1990s, word frequency began to rise rapidly again, increasing by an average of 2,743 occurrences a year and reaching a peak (28,610 occurrences) in 2007. After 2007, it decreased rapidly, with an average of 4,695 occurrences a year. However, only two years later, the frequency of ecological words increased again, at an average rate of 810 occurrences a year, reaching 26,105 occurrences in 2015. Overall, the growth rate of ecological words is only 1/6 of that of economic words. China’s economic activities are always hotter than its ecological activities.

Figure 1. Changes in the frequency of economic words and ecological words of 1946-2015 in the *People’s Daily*. a. Economy-related words, b. Ecology-related words.

The top five high-frequency concepts show the differences in China’s economic and ecological concerns (Fig. 2). In the economic field, the frequency of all popular concepts is higher than 10,000 occurrences. ‘Economic policy’ and ‘economic situation’ (blue line in Fig. 2a) were essentially parallel in the first seven years. The absolute frequency of the ‘economic structure’ (first black line above in Fig. 2a) and ‘economic system’ (second black line above in Fig. 2a) fluctuates by an order of magnitude, resulting in very large variation (Table 2). The concept in Fig. 2b shows a clear grouping: ‘world economy’, ‘rural economy’, ‘collective

economy’ and ‘national economy’ in one group, and ‘commodity economy’ (red line in Fig. 2b) in another lower-frequency group. The ratio of ‘commodity economy’ in economics is close to 1, which means that they are close to the expected value of random copying (Table 1). These popular concepts also reflect different foci in economic field. ‘Economic structure’, ‘economic policy’, ‘economic system’ and ‘economic situation’ are elements of economic development, while ‘world economy’, ‘rural economy’, ‘collective economy’ and ‘national economy’ are concepts with different scale of economic observation.

Table 1. Values of NV/v for the top 10 concepts, 2008-2013, tracked in Figure 2.

Different to economic field, ecological field shows stronger sensitivity to policies, such as ‘ecological environment’ and ‘ecological civilization’, as well as to ecological problems that are ‘people-oriented’ and affect human survival and development, such as ‘agricultural ecology’, ‘marine ecology’ and ‘forest ecology’. In terms of historical changes, the frequency of the ‘ecological environment’ (red line in Fig. 2c) is one order of magnitude higher than that of other concepts. ‘Ecological environment’ first appeared in the 1960s and has gradually increased since then. In 1981, it became the most used concept and continued to rank 1st for the next almost 35 years (except for the year of 2012 and 2013), which explains its very high variation value (Table 1). In contrast, ‘ecological civilization’ did not exist before 1995 but has increased significantly since 2005. After 2007, it experienced a four-year stable period and ranked 1st in 2012 and 2013 with yearly occurrence reaches 931 and 1023 respectively. The frequency of ‘ecological civilization’ has increased by two orders of magnitude in 10 years. Despite such increases, no other concept attains the frequency of the ‘ecological environment’. When ecology is the central term of the concept, the frequency fluctuation is generally low. Concepts like ‘marine ecology’ (blue line in Fig. 2d) showed a stable and periodic increase in frequency and ‘agricultural ecology’ (red line in Fig. 2d) declined continuously and periodically. The ratio of ‘agricultural ecology’ and ‘forest ecology’ in ecology is close to 1, which means that they are close to the expected value of random copying (Table 1).

Figure 2. Frequency of the top 10 concepts from 2003 to 2013. Shown are the two structures for the concepts: a. Econ (economic) + noun, b. noun + Econ (economy), c. Ecol (ecological) + noun, and d. noun + Ecol (ecology). Y axes are logarithmic.

The turnover rate is affected by new concept mutation or concept innovation. As a measurement of innovation or mutation, we calculate the conceptual mutation rate (μ). The mutation rate of new concepts is always higher for the economy than for ecology, which indicates that new phenomena or other elements appear faster in the economic field (Table 2). The turnover rate is affected by new concept mutation or concept innovation. As a measure of innovation or mutation, we calculate the conceptual mutation rate (μ).

From 1975 to 2015, the mutation rate of both economic and ecological words increased as a whole, although the mutation rate of economic words was always higher than that of ecological words (Table 2), which indicates that new phenomena or other elements appear faster in the economic field (Table 2).

The mutation rates of both concepts reached the highest value in 2015, with 50 economic words and 35 ecological words per 1000 reports. After 2000, the difference between economic concepts and ecological concepts decreased. In 2000, the mutation rate of economic concepts (approximately 0.4×10^{-3}) was twice that of ecological concepts (approximately 0.15×10^{-3}) but had decreased to only a 1.1-fold difference between these concepts in 2005. Before 2000, the number of mutations in the economic vocabulary increased rapidly and then decreased until 2005, with a subsequent increase. The growth rate of the economic vocabulary was the largest (233%) from 1980 to 1985, at 4.67 occurrences that from 1975 to 1980 (50%). The mutation rate of ecological words changed little before 1995 but increased rapidly after 1995 and then levelled off. The growth rate of ecological words from 2000 to 2005 (the largest, 231%) was 23 occurrences that from 1985 to 1990 (10%).

Table 2. The mutation of economic concepts and ecological concepts in the *People’s Daily*, from 1975 to 2015. Econ denotes econ-N and N-econ, Ecol denotes ecol-N and N-ecol, $N\mu$ is the number of new concepts, N is the total number of concepts or concepts frequencies of the year, and μ is the invention fraction.

From 1980 to 2010, the cumulative frequency distribution of economic concepts and ecological concepts in China showed a power-law distribution over time in four time segments (Fig. 3). In 1980, the power of economic words was $\beta = -0.46$, showing a long tail distribution (Fig. 3a); that is, the usage frequency of a few economic words with the highest usage rate is very high, whereas the use frequency of economic words with the lowest usage rate is very low. At the same time, the development of Chinese ecological words was $\beta = -0.13$, indicating only a small frequency difference between ecological hot and non-hot words. In 1990, the β of economic words increased to -0.5 (Fig. 3b), indicating an increased difference between high-frequency words and low-frequency words, which was enhanced by selection. The β of ecological words changed to -0.08 , indicating that word frequency was becoming increasingly neutral. By 2000, the β of economic words had further changed to -0.6 , showing a further strengthening in the choice of words. The β of ecological words remained -0.08 , and its random variation characteristics remained unchanged (Fig. 3c). However, by 2010, the β of economic words had decreased to -0.26 , while that of ecological words had increased to -0.09 (Fig. 3d), indicating that the frequency of economic words had become random, and the selection of ecological words had become stronger.

Figure 3. Cumulative frequency distribution of all economic and ecological concepts of *People's Daily*. The filled circle represents the distribution of economic concepts and the open circle represents the distribution of ecological concepts. a. 1980, b. 1990, c. 2000, d. 2010.

From 1946 to 1978, the turnover curve of economic words was concave (first slow and then fast), $b = 0.73$. At this stage, the change in high-frequency words was faster than that in non-high-frequency words (Fig. 4a). In other words, the change in economic words was very active, and popular economic words were not 'fixed'. Economic words were subject to anti-conformist selection. After the reform and opening up (1979), there was no significant difference between the turnover curve of economic words and the neutral prediction value (Fig. 4b). At this stage, the turnover of economic words was close to neutral. Notably, compared with the period prior to the year of reform and opening up, the turnover of economic words decreased as a whole following the reform. The actual turnover value of economic words in the *People's Daily* was lower than the neutral expectation ($\beta \sim 0.86$). The turnover curve of ecological words before the reform and opening up policy was convex (first fast and then slow), $b = 0.92$ (Fig. 4c). After the reform and opening up in 1978, the turnover of ecological words remained convex, and index b increased to 1.25 (Fig. 4d). In these two stages, the change in high-frequency ecological words was slower than that in non-high-frequency words. In other words, words with high frequency, or popular ecological words, were 'fixed'. Ecological words were subject to conformist selection (frequency-dependent bias).

Figure 4 Turnover in the popularity of ecology- related and economy-related words. The dashed lines represent $b = 0.86$, and solid lines are fit to the data. a. economy-related words (including both Econ-N and N-Econ concepts) from 1946 to 1978, b. economy-related words from 1979 to 2015, c. ecology-related words (including both Ecol-N and N-Ecol concepts) from 1946 to 1978, d. ecology-related words from 1979 to 2015.

Discussion

The frequency of ecological and economic concepts can reflect a society's ideas about sustainability. From a historical perspective, a connection between China's economic development and language usage can be established. From formal governmental documents and administrative policies to daily expressions about people's livelihoods and social lives, developing the economy appears to be the top priority (Liu 2010). One phenomenon observed in this study was the 'emergence' of economic concepts within a short period, which manifests the vigour and creativity of China's economy. Early economic concepts may be described as subject to anti-conformist bias, and these concepts have maintained a high proportion of concept innovation rates since the founding of PR China. With the further development of China's economy and its gradual integration with the international market and world economy, the relative frequency of innovation in economic concepts declined, and each concept acquired a stable *niche*. The entry and loss of concepts remained within a certain frequency range, and economic concept variance and frequency data showed that, with the passage of time, the frequency of and variance in new concepts have shown a downwards trend. Although the overall average

frequency does not appear to be maintained at a similar level, the turnover rate of popular concepts is close to the expected value of the neutral model, which indicates that economic concepts have entered a process of cultural drift. This finding does not nullify the intrinsic value of concepts but emphasizes the weakness of the selection intensity involved, which is caused by the mixed forces of internal and external economic development and a new understanding of economic growth. As in the neutral theory of population genetics, most evolutionary changes are caused by the random genetic drift of mutant alleles that are selectively nearly equivalent (Kimura 1983). The evolution of economic concepts demonstrated in these findings implies that these concepts have also experienced a neutral evolutionary process.

Ecological concepts appeared four decades after the founding of PR China. Sustainable development ideas have emerged across the international community since the 1980s, and China has taken a series of actions to protect the environment and has brought forth a series of policies and regulations to strengthen its ecological civilization construction strategy. Public media quickly responds when reporting governmental decisions and resonates with social preference and public attention. The growth rate of innovation in ecological concepts surpassed that for economic concepts in a short period. However, the prevalent selection force underlining this dynamic is primarily conformity bias, which indicates the selection of a few popular concepts and implies a weaker degree of diversity and a vigorous language system to describe ecological ideas. These popular ecological concepts are directly derived from national strategic slogans and ecological construction priorities, and the frequencies of popular concepts are significantly higher than those of other concepts, resulting in a ‘winner-takes-all’ distribution (Hahn and Bentley 2003; Bentley et al. 2004). The turnover rate in the later period indicates that the force of the frequency-dependent copying bias is stronger later than in the earlier period, which means that more focused attention is being directed to a certain specific area year after year in the process of constructing an ecological civilization. Through the variability analysis of popular concepts (Table 2), we clarify the two possibilities that may have caused the concave function for the turnover rate. The higher variability of ecology when functioning as a modifier noun indicates stronger conformity due to context bias rather than content bias, which suggests that ecological ideas are experiencing a stronger selective force when they merge into other social spheres and that the focus of public attention constantly shifts, which leads to a high variability value. However, a closer investigation of the popular concepts can establish linkages demonstrating consistency between public attention and national strategy.

From a linguistic perspective, the overall variabilities when ecology and economy serve as the head noun (N-ecol or N-econ) are smaller than those when they function as the modifier (ecol-N or econ-N). This result indicates that when ecology and economy are integrated with other social activities, their absolute frequency may experience greater variation when they are applied within the discipline, e.g., ‘ecological civilization’, ‘ecological environment’, and ‘economic structure’ are concepts that enter the top list within a very short period. These concepts are positively selected and copied extensively in the media. The diachronic changes in popular concepts also differ in the top list of concepts. The government’s strategy and strong will to improve China’s ecology are expressed by concepts such as ‘ecological environment’ and ‘ecological civilization’. The diversity and dynamics of economic concepts tend to experience negative frequency selection. In addition, popular concepts and their dynamics reflect that local culture exerts a stronger centripetal force on language than does centrifugal force from overseas. The low level of overlap for high-frequency popular concepts fully demonstrates the ethno-demographic features of a unique nationality, regionalism, and sociality in understanding and focusing on protecting the environment and developing the economy. Moreover, the evolutionary process of concept usage can lead to a new perspective on the social understanding of the trade-off between the economy and ecology in which the Chinese government plays a leading role, with all sectors of society actively involved. Ecological concepts appear to experience conformity bias, which means that popular concepts might be copied from the governmental sphere to society and into people’s daily usage. In contrast, economic concepts seem to experience anti-conformist bias and neutral processes in the recent data, which indicate an abundance of innovation and unbiased transmission in daily language usage.

Conclusion

In China, the dynamics of both economic and ecological concepts in mainstream newspapers reflect govern-

ment policy and social activity hotspots for sustainability. The reform and opening up policy profoundly changed the structure of the Chinese economy and incentivized a more diversified and vigorous economic development system. The periodical and consistent emergence of abundant economy-related words in the last four decades reflects an increasingly healthier and more resilient economic development pattern. The shifting of popular economic ideas reveals the mobility of the system and greater innovation potential in economy-related areas. In comparison with economic ideas, the popular ecological ideas reveal a stronger conformist tendency and more force from political decisions than independent social forces in shaping their dynamics. A governmental initiative in ecological construction and protection accelerates the transmission of ecological concepts and enhances the recognition of sustainability ideas in a much shorter period than for economic ideas. However, the lower level of innovative and creative new concepts in ecological areas implies the shortage of vitality in developing ecological ideas. Nonetheless, we also assert that if the data were expanded to include today, the result might be different due to the ecological restoration achievements China has made in the intervening years. With the approaching 2030 Agenda of Sustainable Development and China's entry into a new phase of ecological civilization, stimulating and incubating more diversified and resilient ecological knowledge and ideas and transferring them into daily usage will facilitate the linkage between knowledge and action and will, in return, foster the transition to sustainability society and the attainment of sustainable development goals.

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Table 1. Values of NV/v for the top 10 concepts, 2008-2013, tracked in Figure 2.

Category	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Ave.
ECON-N	55.16	16.94	42.33	20.60	0.79	27.16 (21)
N-ECON	8.96	17.33	3.37	6.07	1.18	7.38 (6)
ECOL-N	5.69	1.09	3.03	2.00	66.93	15.75 (28)
N-ECOL	0.35	1.14	1.23	31.30	9.26	8.66(13)

Number in parentheses gives the standard error on the trailing digits.

Table 2. The mutation of economic concepts and ecological concepts in the *People's Daily*, from 1975 to 2015.

Year	$N\mu$ (Econ)	$N\mu$ (Ecol)	N (all phrases)	μ (Econ)	μ (Ecol)
1975	1187	20	36589803	0.00%	0.00%
1980	3117	437	45310424	0.01%	0.00%
1985	12763	1985	60402011	0.02%	0.00%
1990	15717	3043	63133238	0.02%	0.01%
1995	22982	3630	63236892	0.04%	0.01%
2000	33410	12038	76579938	0.04%	0.02%
2005	25313	21145	70794106	0.04%	0.03%
2010	19961	16029	43465357	0.05%	0.04%
2015	22983	16425	42318024	0.05%	0.04%

Econ denotes econ-N and N-econ, Ecol denotes ecol-N and N-ecol, $N\mu$ is the number of new concepts, N is the total number of phrases of the year, and μ is the invention fraction.

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