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ECONOMIC EVOLUTION IN CHINA ECOLOGICALLY FRAGILE REGIONS

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Abstract. Economic evolution is considered as being driven by innovation of research and development (R&D) even if regional characteristics usually have critical impacts on various culture-oriented living styles that change in a social transformation dynamically. In documented Chinese history, climate changes and geographic conditions are constraints of the economic evolution in ecologically fragile regions. Lots of unpublished indigenous knowledge of environmental adaptation as a part of culture have been excluded from innovative records. In this research, we review research records of several key factors closely associated with economic evolution in the history of study regions, including climate change, cultural transition, economic base, resource endowment and transportation accessibility. By surveying previous research records and contents, we examine the paths of economic evolution mixed with adaptive cultures response to climate change in each region and draw conclusions that (1) the economic evolution with regional climate changes interactively experience three stages of culture-hindered, culture-mixed, and culture-impelled adaptation diversely; (2) regions that have higher economic performance with less innovative records highly likely have a relatively large number of indigenous knowledge unpublished throughout cultural evolution; and (3) English world has research preference to the regions that have lower economic performance with a distinctive culture in China.

Keywords. China; Climate changes; Culture; Economic evolution; Ecologically fragile region

1. Introduction

The theory of economic evolution has argued that the endogenous innovation drives economic growth whether or not with a consideration of Location Theory (North, 1955; Solow, 1956, 1957; Arrow, 1962). From the perspective of endogenous innovation, philosophical explanations of economic evolution borrow some basic ideas from either Darwin's natural selection or Lamarck's biological evolution (Hodgson and Knudsen, 2006). In the process of economic evolution, it is debatable that innovations are spontaneous

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free wills or environmental adaptation for survival. Joseph Alois Schumpeter (1934) proposed that firms' behaviours of the investment of the Research & Development (R&D) reflect the capability of innovations and entrepreneurships, indeed, which are endogenous engines to drive economic growth through a non-linear path back to a series of critical points in a dynamic equilibrium (Schumpeter and Opie, 1934; Nelson and Winter, 1982; Winter, 2003). It indicates that R&D can also lead to inefficient investment (Hunt, 2006). Ahmed (1998) addressed that innovation is also a culture because people who are living in different region create various 'innovation cultures and climates'. In those ecological fragile regions, innovation culture does not only have been distorting abstractive innovation climate but also have statistically significant impacts on natural climate and environmental change in the process of economic evolution (Adger, 1999; Adger *et al.*, 2013; Leonard *et al.*, 2013).

From the perspective of Location Theory, climatic conditions, resource endowments, transportation cost and local culture have been always regarded as constraints of maximizing firms' profits and individuals' utilities, thus, interrupting and reshaping the path of economic growth (North, 1955). Both the autonomous factors and the export based markets directly affect the path of regional development, but the debates on which one is more efficiently has no ending yet (Audretsch, 1998). To explain the capital accumulation in a new business circle, neoclassical theory tries to involve viewpoints of public finance, input–output analysis and Nash Equilibrium (Groves and Ledyard, 1977; Duchin, 1992; Fujita and Thisse, 1996; Fujita and Krugman, 2004). These studies have discussed market failures challenging the rational assumptions of theoretical deduction and induction in classical economics about resource allocation, income equality and complete information. Even so, it is very complicated to delineate a path of regional economic growth. In 20th century, the development of intergovernmental activities, complex studies of climate change and experimental studies on individuals' or firms' behaviours have been strikingly propelled to minimize the potential losses of climate change and lower the uncertainties of socioeconomic behaviours. Such that targets of development are to fulfil sustainable development rather than 'creative destruction' (Gowdy, 2008).

Regional specific impacts of climate change drive global concerns when climatic condition and geographic information have been discussed increasingly to become more important to regional development than before. For instance, a challenge to evolutionary economics is to test and assess uncertain shocks and irrational behaviours that affect economic development from the perspective of Location Theory within social dynamics. Academic debates about these non-mainstream points of views have also drawn attentions widely. Stern's paper, *the economics of climate change* (2006), were fiercely criticized by some mainstream of economists (Nordhaus, 2007; Weitzman, 2007; Dasgupta, 2007), and the paper had been under reviewed for two years before finally published on the *American Economic Review* in 2008 (Stern, 2008). These mainstream economists questioned on how large impacts of climate changes on the discounted intergenerational benefits, income inequality and economic efficiency of regional development. Weitzman (2009) even criticized the uncertainty of estimated results on the economic impacts of catastrophic climate change. Despite all that critical comments were strong enough, empirical studies have provided evidence that the spatial distribution of economic activities has been reshaped by these climatic conditions and geographic characteristics. For instance, Zheng and Kahn (2008) have pointed out environmental amenities as key factors having statistically significant impacts on real estate pricing in urban area of China. In addition, due to specific geographic characteristics of a location, the maladaptive climate of industrial production has led to dense pollution in urban area. For example, coastal cities with high moist and less windy days have high possibility of severe air pollution and poor quality of life (Zheng *et al.*, 2014). Especially, arable land suffering from degradation of natural conditions and other unpredictable natural hazards have led to tremendously economic losses of agricultural production (Deschenes and Greenstone, 2007). In contrast to these negative effects of climate changes, warmer weather with more precipitation benefit to agricultural production in relatively higher altitude mountainous region due to earlier germination than before (Mendelsohn *et al.*, 1994). Thus, beyond the risk management

of natural hazards, climatic condition and regional characteristics are critical factors of economic evolution needed to be examined from the perspective of Location Theory.

Location accessibility and transportation cost significantly influence on consumers' choices, so that have inevitable impacts on regional agglomeration (Keebleand *et al.*, 1982; Vickerman *et al.*, 1999; Gutiérrez, 2001). High transportation accessibility fosters commercial trade and promotes multi-level communication among various social groups across different regions. Intuitively, knowledge spillover has close relationship with physical distance (Andersson and Karlsson, 2007). It enlightens that studies on regional economic evolution have to take local characteristics into considerations. Hence, Rietveld (1989) has proposed that infrastructure can be a production factor influencing regional private investments and interregional trades; and, government investment on infrastructure can be an endogenous factor to drive regional economic growth (Albalate *et al.*, 2012). Especially, the urban–rural coordinative development has been stimulated by high standard transportation network (Ozbay *et al.*, 2003). Central Place Theory has emphasized that urban expansion with advanced transportation accessibility absorb peri-urban employments moving into cities; and supervene with cheap contracts of land use and other resources utilization at urban fringes to improve the quality of life in urban communities (King, 1985; Adell, 1999). Thereafter, those close connections prosper economic activities, concurrently import and export local resources for political or military purposes. Hence, regional social norms across different cultures are always challenged by some prejudice and discrimination. Cultural elements within economic evolution have uncertain impacts on regional equality. Under this circumstance, the effects of transportation accessibility for improving regional equality are controversial, and needs to be reexamined for different regions, so that Location Theory reinforces that advanced transportation is a critical role to determine the pattern of regional agglomeration.

Relatively scarcity of resource endowments and their uneven distribution reshape social networks in a stochastic process, so that to maximize firms' profits or individuals' utilities is not a divine guide of economic development (Alchian, 1950; Jackson and Watts, 2002; Martin and Sunley, 2006; Glückler, 2007). Studies on evolution of economic theory, thus, is challenged and developed by both natural-science-based empirical analysis and social-science-based experimental results of irrational behaviours tests (Kelm, 1997). Nevertheless, neoclassical economists still stand for laissez-faire and believe economic evolution is from economic system itself (Lo, 2004). Recall evolution of market efficiency, Samuelson (1952, 1954) has addressed that the tendency of economic growth under the linear assumption prone to a stationary time series, and other supplementary theories have tried to explain and fix the uncertainty of market failure. However, the inequality of market power across different polities generates price discrimination, increase transaction cost, lead to inefficient resource allocation, and fundamentally challenge the grounded assumption of unbounded resource utilization over time. Sen (1977) has stated that there are positive and negative freedoms that devote to social inequality. Because resource-based exporting markets distort the assumption of a close economy, interregional and international free trades actually are not free (Isham *et al.*, 2005). Nowadays, it is straightforward that natural resource is one of the most important production factors discussed by energy economists and climatic scientists (Bosello *et al.*, 2007). Research focuses retrospect the hardcore of economics to study efficiency of resource allocation when market failure breaks through the fairy tale of market efficiency, and to review the policy-oriented or private investment of R&D as a critical role to interpose trade-offs for mitigating potential economic losses (Sethi and Somanathan, 1996).

Theoretical studies have examined the path of economic growth in line with endogenous innovation; while empirical analysis have argued that the effects of the initial level of economic base is also a determinate factor (Andrews, 1953). Nelson and Beyers (1998) have examined western rural area of U.S. experienced population growth in 1990s that illustrates that the traditional natural-resource-based economic base is somehow contributing more than other factors to regional economic growth. In those large developing countries, such like China, India and Brazil, the economic development of ecologically fragile regions is used to lack of well-planned schemes. As personal per capita income increases, rich

people require higher standards of clean water, air and blue sky. Industrial production gradually moves out from cities to rural regions, so that rural regions undertake risks of pollution and environmental degradation and having unexpected impacts on the health of future generation, particularly at urban fringes (Homer-Dixon, 1994). Especially, regional economic development in ecologically fragile regions highly depends on natural resource endowments and traditional economic base. Such that leads to the regional and environmental inequality getting worse than before. In recent decades, global warming rises up world attention to ecosystem and natural environment protection. The studies of the regional planning management of the adaptation response to climate change are looking for the thresholds of environmental vulnerability and ecosystem resilience with consideration of both economic base and regional characteristics (Simmie and Martin, 2010). Richardson (1985) has emphasized that there is a long history of documented reviews on economic base model which are developed towards regional case studies for decision-making of economic development with more considerations of local multipliers and cultural elements.

Economic evolution has cultural preference (Bowles, 1998). Neo-institutional theory proposes to minimize transaction cost to remedy market failure and save economic cost of irrational behaviours (Lin, 2007). In a process of learning-by-doing, local culture has itself market of knowledge and itself evolutionary process (Lin, 2008), which creates a unique path of economic growth involving various components of resource endowments, natural environmental conditions, and idiomatical industries in a specific region (Carlsson and Stankiewicz, 1991). Multinational Corporation towards local marketing strategy has suffered from maladaptive regional culture so that had to pay high cost of 'tuition' to learn how to cooperate with local partners (Hennart and Larimo, 1998; Buckley and Casson, 1998; Alden *et al.*, 1999). In those cultural transitions, social norms have been reshaped by global multi-cultural elements, and that further influence on public opinions (Chatman and Flynn, 2001). However, in various social transformations, some local cultures are not influenced by importing cultural elements, while some others do. The consequence of economic evolution, thus, can be determined by cultural transitions critically, or can influence cultural evolution endogenously.

Given the above information, we aim to study the economic evolution in ecologically fragile regions of China. In the rest of this paper, we will first introduce background information of the study regions in underdeveloped western China; then, geographic characteristics of each region are summarized in Section 3; sequentially, the methodology and data statistics from Google Scholar search engine are described in Section 4; based on comparison of research records, research questions are remarked and analysed in Section 5; and finally, this paper ends by discussion of different cultural stages.

2. Background Information

Ecologically fragile regions of China are almost all located in western China, which cover 6.87 million km^2, accounting for 71.54% of the total area of China. According to China Council for International Cooperation on Environment and Development (CCICED) (2012) Annual General Meeting Report, more than 360 million population including 55 minority ethnic groups inhabit there, accounting for 27.04% of the total population of China in 2011. From the perspective of strategic development, other details of ecological vulnerability of western China are shown in Table 1.

In this study, there are five representative geomorphic units selected from ecologically fragile regions of western China, including 10 administrative divisions: Tibet autonomous region (hereinafter abbreviated to Tibet) and Qinghai Province on the Qinghai-Tibet Plateau; Yunnan Province and Guizhou Province on the Yunnan-Guizhou Plateau; Sichuan Province and Chongqing Municipality in the Sichuan Basin; Shaanxi Province, Shanxi Province and Ningxia Hui Autonomous Region (hereinafter abbreviated to Ningxia) on the Loess Plateau; and Xinjiang Uygur Autonomous Region (hereinafter abbreviated to Xinjiang) as the largest province located at the northwestern corner of

Table 1. Overview of Ecological Vulnerability of Western China

Resource and energy security	• Accounting for 81.1% of exploitable water resources[2] • All of 171 types of mineral resources • 132 types of mineral reserves have been proven • Accounting for 67% of China's fossil energy • Accounting for 65% of China's renewable energy sources[3]
Ecological security	• Owning 85% of China's national nature reserve areas[4] • Owning 70% of the state-level protected ecosystem and species • Accounting for more than 65% of ecological service value of China[5]
Poverty alleviation	• Accounting for 66% of China's poverty population[6] • Poverty rate is almost 17 times that of the eastern area • 95% of absolute poverty population of China are in minority nationality areas, remote areas, border areas and ecologically fragile area, and these areas are mainly in western region • The illiteracy rate among adults (above the age of 15) is 5.41%, 1.33% higher than the national average[7]
Urbanization	• Urbanization rate is as low as 28.70%, which is 7.52% lower than the national average in 2000; after 10 years development, the urbanization rate had increased to 40.48%, which is still 9.20% lower than the national average.
Industry development	• GDP per capita is 25% lower than the national average • Output of energy and mining industry account for 63.41% of the regional output of industry. • Emissions of the 'three wastes' per 10,000 yuan industrial value-added is 1.1 times more than national level
Transformation of economic structure Domestic demand playing larger role	• Western China is a vast area, with an economy below other parts of China. There is huge potential for expanding regional domestic demand.

Notes: Data source from [1]NBSC (National Bureau of Statistics of China). *China Statistical Yearbook* (2011), Beijing; [2](Kong and Hu, 2003); [3]NBSC (2009); [4](Quan *et al.,* 2011); [5]Ecological Environment Protection Research Center (2009); [6]NBSC (2010); [7]NBSC (2011).

China (Figure 1). The total area of these study regions accounts for four fifths of the whole western China.

3. Geographical Conditions

The Qinghai-Tibet Plateau (25°–40°N,74°–104°E) is surrounded by the Kunlun Mountains, the Hengduan Mountains and the Himalayas, which is the largest plateau in China and the highest plateau on the Earth. The most part of the Qinghai-Tibet Plateau is located in southwestern China, covering Tibet and Qinghai Province, including a small part of Sichuan Province, Gansu Province, Yunnan Province and Xinjiang. Due to high altitude, there are less rainfall and quite dry and thin air solar radiation is relatively strong; and, the temperature is relatively low with spatial variation mainly because regional climate changes interact with complex and diverse terrain of microwatersheds. It leads to average temperature in July between 15 and 20 °C which is much lower than other regions' at the same latitude; especially above

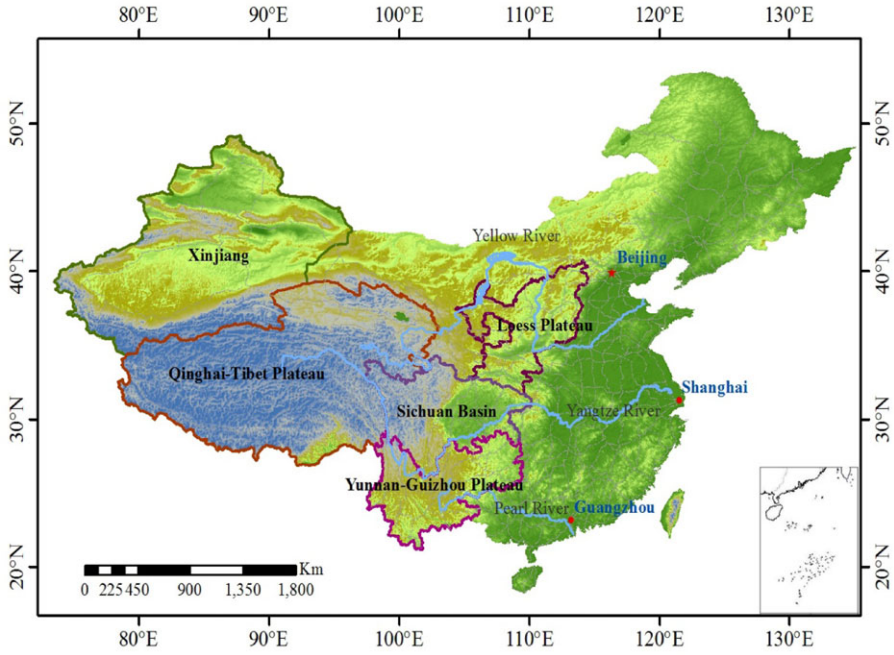

Figure 1. Five Study Regions in a Map of China: The Qinghai-Tibet Plateau, the Yunnan-Guizhou Plateau, the Loess Plateau, the Sichuan Basin, and the Xinjiang Region.

4500 m, the average temperature is below 0 °C, and annually average minimum temperature even around –10 to –15 °C. In general, a maximum of monthly average temperature is still lower than 10 °C in many regions of the Qinghai-Tibet Plateau (Mo *et al.*, 2004), and the northern Tibet Plateau (the Bayankala Mountain, the Maduo and the Qingshui River and the Qilian Mountains in Toler) is the centre of frigid highlands with the lowest temperature in China.

The Sichuan Basin (27–32°N, 101–110°E), the centre of China and the centre of south Asia, is located in the upstream of the Yangtze River mainly occupied by Sichuan Province and Chongqing Municipality with a total area of 26 million km^2. The Sichuan Basin are topographically surrounded by connecting mountains at elevation of 2000–3000 m, bordering on the east of the Qinghai-Tibet Plateau and the Hengduan Mountains; beside the west of the Mountains of Hubei and Hunan Province; adjacent to the south of the Qinling Mountain across the Loess Plateau; and, bordering on the north of the Yunnan-Guizhou Plateau. Due to these topographical characteristics, temperature in Sichuan basin is higher than in other regions at the same latitude. Average temperature in the coldest month is between 5 and 8 °C; and, the minimum temperature is between –6 and –2 °C. The temperature in east side of the basin is higher than the west side, and the south side is higher than the north side. With rare frost and snow, the annual rainfall of the Sichuan Basin is between 1000 and 1300 mm; and, there are abundant precipitations at the edge of the basin where the maximum daily rainfall is between 300 and 500 mm (Li *et al.*, 2015). Moreover, clouds usually stay at relatively low altitude resulting in much foggy and cloudy weather.

The Yunnan-Guizhou Plateau (23°–27°N, 100°–110°E) is the fourth largest plateau with the altitude of 1000–2000 m located in southwestern China. It is adjacent to the Hengduan Mountains on the west side; beside the Sichuan Basin on the north side; next to the Xuefeng Mountain in Hunan Province on

the east side; and border on Myanmar, Laos and Vietnam on the southwest corner. Yunnan Province and Guizhou Province are the main part of the Yunnan-Guizhou Plateau. Both regions belong to the humid subtropical zone with the subtropical monsoon climate (except *xishuangbanna* which is the tropical monsoon climate). Climate among micro-watersheds are strikingly different due to the difference of altitude and atmospheric circulation; and the annual temperature is about 12–l6 °C varied in terms of the complex terrain (Zhao, 1999), but the difference of annual temperature is moderate because of the relatively warm winters and cool summers.

The Xinjiang Region (35°–50°N, 75°–95°E) is divided into the northern and southern parts by the Tianshan Mountains. The northern Xinjiang has the second largest desert in China – the Gurbantunggut Desert – in the Junggar Basin between the Tianshan Mountains and the Altai Mountains. The southern Xinjiang has the Turpan Depression on the east and the Tarim Basin on the west. The Turpan Depression includes the fourth lowest exposed point on the Earth's surface. The Tarim Basin is between the Tianshan Mountains and the Kunlun Mountains, and inside of which has the largest desert in China – the Taklimakan Desert. Because the Xinjiang is located in deep landlocked region far away from the ocean and surrounded by high mountains, the marine moisture is not easy to enter. Such terrain forms a distinctive temperate continental climate with undulate daytime temperature, long lasting sunshine (annual sunshine time about 2500–3500 hours), less precipitation and dry air. The average annual rainfall in the Xinjiang is about 150 mm with great variation in different areas. The temperature is higher in the south than in the north. In the coldest month (January), the average temperature in Junggar Basin is below –20 °C; and, in the hottest month (July), the average temperature in Turpan is over 33 °C. The Turpan Depression is the hottest and driest area in China, which is so called the 'Fire Island'. The absolute maximum temperature once reached up to 48.9 °C in the city (Gong, 2007), and it was the highest temperature record in Chinese history of meteorological observation.

The Loess Plateau (34°–40°N, 103°–114°E), also known as the Black-Golden Plateau, is covered by the largest number of loess in the world, covering the vast region from the west of the Taihang Mountains to the east of the Riyue Mountain in Qinghai Province, from the south of the Great Wall to the north of the Guanzhong Plain. It is located in China's second-stage ladder of terrain with an area of 620,000 km^2 and the altitude from 800 to 3,000 m, mainly occupied by Shaanxi Province, Shanxi Province, Ningxia Hui Autonomous Region, southeastern Gansu Province, and a small part of northeastern Qinghai Province. The average annual temperature on the Loess Plateau is about 8–14 °C, with a (warm) temperate (continental) monsoon climate. In winter and spring, it is cold, dry and sandy due to the polar air mass; in summer and autumn, it is quite hot and much rainy due to the western Pacific subtropical high pressure and the Indian Ocean low pressure. The average annual rainfall of the Loess Plateau is about 466 mm, and decreasingly spatially distributed from 600 to 700 mm in southeast sub-humid area, to 300 to 400 mm in central semi-arid area, and continually to 100 to 200 mm in northwest arid area. Sixety-five percent of rainfall occurs in summer, and usually 30% of annual precipitation occurs at one-time rainfall, leading to severe soil erosion on the Loess Plateau (Zhang *et al.*, 2012).

4. Method and Data Statistics

A paradigm labelled the 'cluster approach' means that those contrary research results from different research studies are reclassified for pointing out some novel findings or research biases (Light and Smith, 1971). The term of 'meta-analysis' is a comprehensive expansion from the 'cluster approach', which was firstly named to represent the analysis of analyses, as well as to refer to the statistical analysis of a large collection of individual studies' results for the purpose of integrated findings (Glass, 1976, 1984). This method hence has been widely used for natural and social science studies because it emphasizes and summarizes the nuances of previous research findings about a similar or the same research question, objectively examining previous literatures and generally qualifying some conclusions, in order to yield an

unbiased conclusion from both quantitative and qualitative summaries of empirical analysis past (Egger *et al.*, 1997). However, the meta-analysis is limited by investigators' preference to the importance of former research studies that result in the new findings still with some subjective judgments or prejudices consequently; not strong enough to be a critical way to draw conclusions that are supposed to be impartial (Bradley *et al.*, 2014). Applications of the meta-analysis in studies of sociology and psychology, hence, call for a restructured and modified approach which is beyond a standard approach because of cultural diversities and cognitive differences across different ethnic groups (Bandura, 2001; Zhao *et al.*, 2007). In this research, thus, we follow a series of steps on reviews and analyses.

(1) To review 'cultural' adaptation to 'climate change' in 'economic evolution' in each case study region, firstly the count number of the searched records on Google Scholar is assumed to represent the degree of innovative knowledge. Hence, we count the number of the combination of these three word groups to present capability of innovation with cultural-oriented adaptation to climate change in economic evolution in each case study region, and then separately compare with the real GDP and the average annual resident consumption (ARC) in available statistical years; thereafter, we question on endogenous innovative knowledge that supposedly has large contribution to economic evolution in ecologically fragile regions of China.
(2) To know relationship between historical climate changes and cultural evolution in each region, each combination including 'climate change', 'cultural transition', and the name of each region is searched on Google Scholar in English separately; and then, records of historical climate change and severe natural hazards are picked up and compared with chronological changes of dynasties in Chinese history.
(3) To understand the critical role of cultural elements in social transformation under the constraints of climate change and geographical conditions, the comprehensive viewpoints of historical literatures are analysed from the perspectives of literature, poem, folk-custom, architecture, art, religion, language, costume, living style, and local cuisine in each case study region.
(4) To further understand cultural trends having impacts on economic evolution, an assumption is discussed that the life-cycle of a culture has itself stages which are involved into the economic evolution. Evidence of indigenous knowledge and regional characteristics that are representatives of different cultural stages responding to climate changes in economic evolution are reviewed and enumerated in this study.

In a short summary of methods, we have modified the 'serious meta-analysis'. Because the Google Scholar is considered as a recommended academic research engine being used by the most of the universities and academic institutes, we adopt counts of records due to the popularity of Google Scholar for collecting papers and articles including patents records and citations at the very first step. It is straightforward to let readers know how few of the relevant research records have been published relevantly to the keywords in those ecological fragile regions of China. In spite of this, these few publications are representing the improvement of civilization apparently presenting the advanced knowledge in human history and published in English at higher ranking journals. We assume the 'documented knowledge' is not always representing human innovation, because cultural transformation and adaptation of natural environment for survival are somehow indeed excluded or being considered as common senses and being accepted that are less important than the innovation of higher advanced technology. We thereby look over the relationship between the performance of economic indicators and the 'culture' elements in the 'documented knowledge' based on the counts of key words (rather than using indicators of education level or other accountable modern cultural indicators proposed by some organizations or programs like UNRISD-UNESCO). If this relationship is statistically significant in 'documented knowledge' according to the analysis, those unobserved cultural changes and adaptive transformation in a long chronological period are inferred more important than we have learnt from the documents (because many western

Table 2. Categorized Record Count of the Searched Word Groups in Study regions on Google Scholar

Category	Search terms	Records	Percentage
1	'economic evolution' and 'climate change'	205	7.6
1	'economic evolution' and 'cultural'	963	35.5
1	'climate change' and 'cultural transition'	468	17.3
2	'economic evolution' and 'economic base'	47	1.7
3	'economic evolution' and 'location'	906	33.4
4	'economic evolution' and 'natural environment'	87	3.2
4	'economic evolution' and 'resource endowment'	8	0.3
5	'economic evolution' and 'ruggedness'	25	0.9
	Total	2709	100

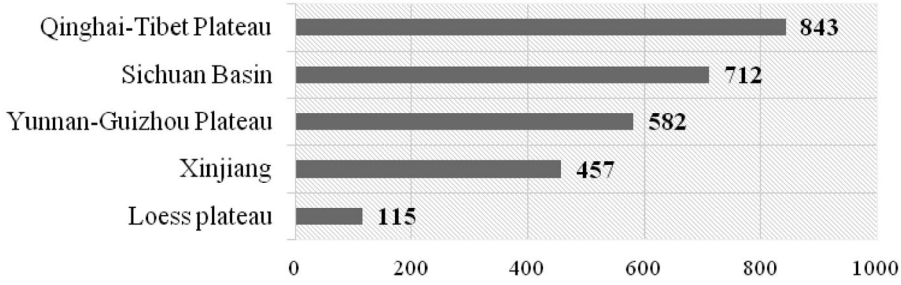

Figure 2. Comparison of the Record Count of the Searched Word Groups in Each Study Regions on Google Scholar.

countries have a very short history unlike Ancient China with a long history of various cultural identities from different minorities in the mixed cultural transformation). Furthermore, we test the relationship between 'culture' elements in the 'documented knowledge' and the performance of economic indicators. If it is statistically significant reported by econometric analysis, it will prove that cultural research as a kind of innovation is critical for economic growth, and each region highly possibly has own distinguished culture-labelled adaptation of regional climate change which has different impacts on regional economic growth because of regional culture *per se*.

On Google Scholar, the publications including a word group of 'economic evolution' during past 200 years is about 25,100 records, but merely 10.8% of which are relevant to our study regions, including replicated records across different categories. Table 2 shows the list of the record count of the combinations of these searched word groups; and, the word groups of 'economic evolution' with 'cultural', 'economic evolution' with 'climate change', and 'cultural transition' and 'climate change' account for 60.4% in total.

There are 6,920 records of the combination of the word groups of 'economic evolution' and 'China'; and approximately 3,330 records of the combination of the word groups of 'innovation' and 'economic evolution' and 'China' on Google Scholar; thus, that the total searched word groups about these study regions still occupy about one third of research records of the 'economic evolution' in 'China'. The record count of 'economic evolution' on the Qinghai-Tibet Plateau is the most; of that in the Sichuan Basin is the second most; and sequentially followed in the order are on the Yunnan-Guizhou Plateau, the Xinjiang and the Loess Plateau (See Figure 2).

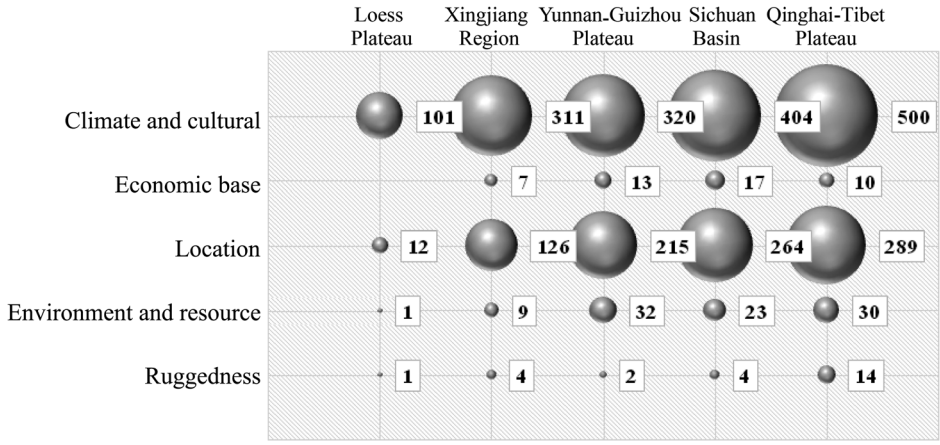

Figure 3. Categorized Comparison of the Record Count of the Searched Word Groups in Study Regions on Google Scholar.

Comparing the record count of different combinations of word groups in each study region on Google Scholar, we find that regional diversity is quite interesting. With regards to 'economic evolution' the record count of publications including 'climate change' and 'cultural' 'location', or 'ruggedness' on Qinghai-Tibet Plateau are the most, while of that on Loess Plateau are the fewest; the record count of publications including 'economic base' in Sichuan Basin are the most recorded, while of that on Loess Plateau are none; and the record count of publications including 'natural environment' or 'resource endowment' on the Yunnan-Guizhou Plateau are the most recorded, while of that on Loess Plateau are the fewest (See Figure 3).

5. Research Findings

Comparing the ranking order of the record count of the five categories of word groups in each study region on Google scholar to the ranking order of the real GDP in each study region, we find that the Qinghai-Tibet Plateau ranking the highest record count but with the lowest economic production, while it is opposite on the Loess Plateau with the lowest record count but ranking the second highest economic production among the five study regions (See Figures 3 and 4).

The changes of scale and trend of the real GDP in study regions during 1993–2014 are shown on the left-hand side in the Figure 4. The economic performance in the Sichuan Basin is ranking the highest among five regions; which on the Loess Plateau is the second highest; and followed in the order by on the Yunnan-Guizhou Plateau, the Xinjiang and the Qinghai-Tibet Plateau. Whereas, the changes of scale and trend of the average annual resident consumption (ARC) (on the right hand side in Figure 4) in all five regions are lower than the national average level respectively. Except on the Qinghai-Tibet Plateau, the changes of scale and trend of ARC in all other four regions are around 10–15 thousands Chinese Yuan. Some remarkable questions are summarized as follows:

i. According to the record count on Google Scholar, the Publications in English including the word group of 'economic evolution' on the Qinghai-Tibet Plateau are the highest number which is much more than that in other ecologically fragile regions of China. However, the actual economic outputs on Qinghai-Tibet Plateau are the lowest in China. If publication records including patents and

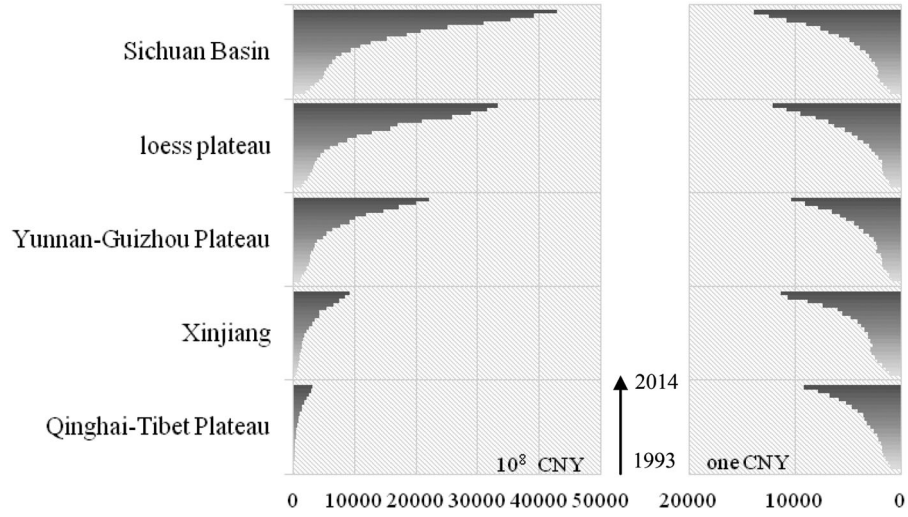

Figure 4. Comparison of the Range of Economic Evolution by Annual GDP (Left) and Average Resident Consumption (Right) in Study Regions, 1993–2014.

citations token regional innovation and being highly relevant to economic growth, why 'economic evolution' on Qinghai-Tibet Plateau of China is a contrary case, and other than innovation, what factors determine to regional economic growth;

ii. In the selected ecologically fragile regions, we find that there is a large difference between the highest and the lowest proportion of the regional economic production contributed to the total GDP of China; while it is a relatively small difference from the highest to the lowest of the ARC in each region, and ARC of these regions even tend to be similar. If there is no difference at very beginning of the human history in education among regions individual in each region should have similar social cognitions and economic behaviours. Then, if the average intelligence level of individuals is similar in the study regions, there should be no statistically significant difference of the capability of innovation and creation that contribute to economic growth, and individuals' consumption demands can token their capabilities of that. If these assumptions are correct, it would be reasonable that ARC in other four regions tend to be similar. However, the question is why people in Sichuan Basin have higher level of ARC, and why the record count that to some extent represents the capability of innovation and creation in five regions are different even if they are all in the ecologically fragile regions of China; and

iii. There are the fewest publication records about the Loess Plateau but which has the second highest economic outputs among study regions. Why ARC at there is close to the highest level in the Sichuan Basin and higher than other three regions. If people in study regions have the similar social cognitions and economic behaviours, and endogenous knowledge should be the largest part of contribution to economic evolution, why there are the fewest research records about the Loess Plateau on Google Scholar in English, and what different kind of paths of 'economic evolution' in five study regions happened in documented Chinese history.

Table 3. Categorized Record Count of the Searched Word Groups about Sichuan Basin on Google Scholar

Category	Search terms	Records	Percentage
1	'economic evolution' and 'climate change'		
1	'economic evolution' and 'cultural'	404	56.7
1	'climate change' and 'cultural transition'		
2	'economic evolution' and 'economic base'	17	2.4
3	'economic evolution' and 'location'	264	37.1
4	'economic evolution' and 'natural environment'	23	3.2
4	'economic evolution' and 'resource endowment'		
5	'economic evolution' and 'ruggedness'	4	0.6
	Total	712	100

5.1 *The Sichuan Basin*

According to the record count of Google Scholar, there are over 56% of records in category 1 including three combinations of key words in Table 3. In the Sichuan Basin, three ancient civilizations in the Baodun ancient city (2500 B.C.), the Sanxingdui ancient city (3000–1000 B.C.), and the Twelve Bridges (or Jinsha culture, 1700–771 B.C.) died out mainly because regional weather got colder and flood hazards during the first Holocene cold stage (Fu, 2006). Because mountains surround the Sichuan Basin, ancient people in the Sichuan Basin used to migrate back and forth between hillside and the Chengdu Plain. This causes those ancient civilizations dying out from specific location in mountainous regions and move to the places with a relatively lower altitude inside of the Sichuan Basin. For instance, *Bā* ethnic culture started from a branch of Neolithic culture in Ancient China. Until the Spring and Autumn and Warring Stage Period (770–221 B.C.), *Bā* ethnic group was assimilated by *Hàn* ethnic group due to colonization by the Qin Dynasty (770–206 B.C.). A large population growth in the south of the Sichuan Basin started from the Western Han Dynasty (206 B.C. to A.D. 24), and increased twice of population in the Eastern Han Dynasty (A.D. 25–220). This is also supposed to be caused by the weather in the north of Sichuan Basin getting colder during the second Holocene cold stage (Hinsch, 1988). Until the Tang Dynasty (A.D. 618–907), temperature in the Sichuan Basin returned to getting warmer (Ge *et al.*, 2010), but ruggedness of terrestrial surface is still a key constraint of regional economic development. The Poetic Genius in Chinese history, Mr. Bai Li, wrote a poem approximately during A.D. 742–744, *Hard Roads in Shu*, translated into English by an American poet (Bynner and Jiang, 1972), for metaphorizing that 'go into the Sichuan Basin is like to go into the Sky'. Thus, the distinctively geographical conditions form a baronial force having huge impacts on economic evolution in the Sichuan Basin.

Indigenous innovation in the Sichuan Basin made great efforts to economic development. The Dujiangyan Irrigation System was constructed by the Royal Court of the Qin Dynasty during 256–251 B.C., which is the longest still being used irrigation system in Chinese history and the world history, so that has influenced the regional cultivation culture profoundly. Cultivation in the Sichuan Basin can be retrospect back to the Sanxingdui ancient civilization (3000–1000 B.C.). After people moved to the Chengdu Plain gradually, population density inside of the Basin became intense over time, and cultivated land suffering from natural disasters became scare which lead that some of them have to go back to live in some low hill mountainous regions. Minority ethnic group in Chongqing, thus, live on fishing and hunting. Local people were used to wearing simple sackcloth and straw sandals, carrying a bamboo pole balanced on their shoulders to hold necessary provisions for a trip, or to take out local products from the mountains to sell at street market. Because people in Chongqing used to take a bamboo pole or a woody stick, they used to be called *bàng bàng army* that means 'stick army'. Due to the humid weather, local

people, like others in many regions of Sichuan, Yunnan, Guizhou, Hubei, and Hunan, prefer to eat spicy and cured food; and, Chongqing is famous for a kind of extreme spicy 'hot pot'. Until 1949, People's Republic of China established, Chongqing was set as a military base and a heavy industry base. Based on this background of strategic development, economic growth in Chongqing was relatively faster than other place in the Sichuan Basin in the past, so that has become a municipality since 1997. In the Sichuan Basin, economic evolution is mainly influenced by population migration and residence shift for struggling with climate changes and geographical conditions. Thus, regional innovation with environmental adaptation in the social transformation is compelled for survival in the Sichuan Basin.

5.2 *The Yunnan-Guizhou Plateau*

According to the record count of Google Scholar, there are over 55% of records in category 1 including three combinations of key words in Table 4. On the Yunnan-Guizhou Plateau, mixed minority culture stimulates regional economic evolution. Yunnan province ranks the number one of the multi-ethnic provinces in China. There are about 25 ethnic groups with a population of over 4000 people in each group. Guizhou Province is also a multi-ethnic province having 18 ethnic groups. In documented Chinese history, Guizhou Province belongs to China in each dynasty. A few wars happened in Guizhou, and the Sino-Japanese War was the largest in the history. While Yunnan province was conquered by outlanders in each dynasty. Multi-culture in this region facilitates social communication and integration. More interestingly, there were very few inner wars among different tribes among different ethnic groups in the history of Yunnan. The highly possible reason behind that is one of three Ancient Tea Horse Roads passing through Yunnan. This road promotes regional development for selling the Pu'er (or Pu-erh) Tea to Tibet and Beijing. Moreover, each ethnic culture has its own strict disciplines and regulations to precaution moral hazards when facing conflicts of economic benefits. For instance, each ethnic group has its own settlements, specific style of clothes and hair accessories. When public resource needs to be shared, the patriarch of the tribe makes decisions or negotiates with the patriarch of another tribe.

Mountainous and semi-mountainous terrain conditions with climate changes in micro-watersheds foster natural habitats and diverse cultures on the Yunnan-Guizhou Plateau. Yunnan Province is across the north tropic, the south subtropical, the mid-subtropical, the northern subtropical, the south temperate, the mid-temperate, and the north temperate (plateau climate), in total seven climate zones. There are also eight large lakes and over 600 rivers with uneven precipitation severely that causes high geo-risk of debris flow. Local people learn ecological knowledge from their ancestors and believe their faiths can survive their

Table 4. Categorized Record Count of the Searched Word Groups about *Yunnan-Guizhou Plateau* on Google Scholar

Category	Search terms	Records	Percentage
1	'economic evolution' and 'climate change'		
1	'economic evolution' and 'cultural'	320	55.0
1	'climate change' and 'cultural transition'		
2	'economic evolution' and 'economic base'	13	2.2
3	'economic evolution' and 'location'	215	36.9
4	'economic evolution' and 'natural environment'	32	5.5
4	'economic evolution' and 'resource endowment'		
5	'economic evolution' and 'ruggedness'	2	0.3
	Total	582	100

lives, as well as protect their settlements (Zhang, 2011). For example, traditions of the ethnic groups, *Yí*, *Wǎ* and *Dé'áng*, set logging ban in the Longshan forestry where is beside their settlements because they believe deities are living there (Guan and Liu, 2014). These kinds of religions highly influence regional environmental conservation and climate adaptation. In Guizhou Province, there are a plenty of mineral resources in mountainous regions including mercury, barite, sandstone, diabase, phosphorus, bauxite, rare earth, magnesium, manganese, gallium, coal, antimony, gold and pyrite, so that Guizhou is so-called 'Coal-sea in South of China'. Climate also varies in micro-watersheds. There is a local old saying, 'four seasons in a Mountain, different weather in ten miles', to illustrate climatic diversity. In addition, the area of rocky desertification and dry river valley are still expanding, which increases natural hazards and endangers agricultural production (Wang *et al.*, 2004). Ancient *Tǔ* ethnic people in Guizhou, thus, construct houses with stilted fir as feet of the houses on semi-mountain to avoid flooding or mud-rock flows. The most of them believe a successful family will bring flourish and prosperity; thus, mixed marriage among minority and *Hàn* ethnic group in mountainous and semi-mountainous regions boost cultural transition (Ran, 2010). This lights up economic evolution through seasonally trading natural resources and absorbing outlanders to settle down in history continually.

5.3 *The Xinjiang Region*

According to the record count of Google Scholar, there are over 68% of records in category 1 including three combinations of key words in Table 5. In documented Chinese history of the Xinjiang Region, human activities occurred in the Neolithic Age. In the Western Han Dynasty (202 B.C. to A.D. 8), it was called Serindia (*Xīyù* in Chinese means the Western Regions). In 138 B.C., the Emperor Wu (156–87 B.C.) of the Western Han Dynasty dispatched envoy Mr. Qian Zhang (164–114 B.C.) to establish diplomatic relation to the countries or tribes in the Western Regions, and to build up the Silk Road. Since the Tang Dynasty (A.D. 618–907), the Xinjiang and its surrounded regions have been governed by Ancient China. Until the Qing Dynasty (A.D. 1636–1912), it was renamed as 'Xinjiang', and then population significantly increased in the Ili City due to military garrison during the Qianlong Emperor (A.D. 1711–1799). In history of the Xinjiang, the pillar industry is animal husbandry. After the People's Republic of China established, the Xinjiang Production and Construction Corps settled down to support local agricultural production. This oasis economic evolution does not only stimulate regional prosperity (Qiao *et al.*, 2009), but also generate social frictions between minority ethnic groups and the Chinese Central Plain Culture (or *Hàn* culture). First, local language is totally different from Chinese mandarin. Public schools of K-12 level teach in Uygur, Han, Kazakh, Kyrgyz, Mongol, Xibe and Russian. Second, over 95% of population

Table 5. Categorized Record Count of the Searched Word Groups about *Xinjiang Region on Google Scholar*

Category	Search terms	Records	Percentage
1	'economic evolution' and 'climate change'		
1	'economic evolution' and 'cultural'	311	68.1
1	'climate change' and 'cultural transition'		
2	'economic evolution' and 'economic base'	7	1.5
3	'economic evolution' and 'location'	126	27.6
4	'economic evolution' and 'natural environment'	9	2.0
4	'economic evolution' and 'resource endowment'		
5	'economic evolution' and 'ruggedness'	4	0.9
	Total	457	100

is not *Hàn* ethnic group people, and most of them believe some religions including Islam, Buddhism, Lamaism (Tibetan Buddhism), Christianism, Catholicism, Orthodox and Shamanism. There are over 24 thousand temples, and over 98% of them are Moslem temples. Third, their etiquettes and customs are quite different from *Hàn* ethnic group.

Climatic factors have critical impacts on changes of people's mood and behaviours (Kasper *et al.*, 1989). Dry and hot weather with large daytime temperature difference and many windy days foster plenty of luscious fruits and local people's ebullient characters. The weather also impels local preference to wear waistcoats, and women to wear a hood. In ancient time, transportation accessibility is quite low in many regions of the Xinjiang. Horses and camels are the main transportation tools, so that local people prefer to wear boots. This makes identify different ethnic groups easily. Due to dry climate, food is easily to be stored and dried which let the Xinjiang be famous for various dry fruits, such like raisin and dried cantaloupe. Because of lacks of diversity of grains, traditional local food is a kind of very dry pancake, named *náng* in Chinese. After 1949, the Xinjiang Production and Construction Corps enter and garrison the Xinjiang. Their highly productive agricultural productions prosper regional economy, but also lead to income inequality that significantly influence on the social frictions and living style of local people. Urbanization breaks the traditions of 'temple life' and leads to diverse ethos serving to various interest groups, so that reshape the path of regional development. Considering the debates about the positive or negative impacts of local Moslem religion on economic evolution (Abuduli, 2010), we cannot make a conclusion about which culture is superior. However, we can conclude that the unique economic evolution in the Xinjiang follows the traditional inheritance and has been influenced by their own cultural force.

5.4 *The Qinghai-Tibet Plateau*

According to the record count of Google Scholar, there are nearly to 60% of records in category 1 including three combinations of key words in Table 6. On the Qinghai-Tibet Plateau, population is much less than other regions in China due to atrocious weather and physical geographic conditions. In the Tang (A.D. 618–907) and the Song (A.D. 960–1279) Dynasties, Qinghai and Tibet was named *TǔFān* in Chinese which was the first regime on the Qinghai-Tibet Plateau; and they were governed by Ancient China from the Yuan Dynasty (A.D. 1271–1368). From the Qing Dynasty (A.D. 1636–1912) to present, the territory of Qinghai and Tib*et* almost were not changed in Chinese history. Local Tibetans had been divided into multi-tribes obeying serf system culture from the Tang Dynasty (A.D. 618–907) to A.D. 1951. Local patriarchal culture is mixed with religion of the Tibetan Buddhism, so that the patrician of each tribe held

Table 6. Categorized Record Count of the Searched Word Groups about *Qinghai-Tibet Plateau* on Google Scholar

Category	Search terms	Records	Percentage
1	'economic evolution' and 'climate change'		
1	'economic evolution' and 'cultural'	500	59.3
1	'climate change' and 'cultural transition'		
2	'economic evolution' and 'economic base'	10	1.2
3	'economic evolution' and 'location'	289	34.3
4	'economic evolution' and 'natural environment'	30	3.6
4	'economic evolution' and 'resource endowment'		
5	'economic evolution' and 'ruggedness'	14	1.7
	Total	843	100

absolute power of institutions in the past. Conflicts between theocracy and democracy had influenced regional political stability all the time. Under this Polity of Caesaropapism, the historical population in Tibet was 0.8 million in total, while Qinghai was near to 1.5 million. After 1949, Qinghai Province has been governed by the P.R. of China; until 1951, the Chinese People's Liberation Army entered in Tibet; until 1965, the present Tibet was established. In recent 50 years, the quality of life represented by the value of the average annual resident consumption (ARC) of Qinghai and Tibet has been improved significantly. According to the statistics of ACR during 1993–2014, local ACR has been close to the level of other regions in ecologically fragile regions of China. Until 2014, population in Tibet reached 3.18 million, and in Qinghai reached 5.83 million.

Mountainous condition and harsh climate limit local people's choices of migration into the Qinghai-Tibet Plateau. Climate change in this region experienced a similar changing process as other regions in documented Chinese history, but with a relatively larger range of changes in temperature and precipitation (Song *et al.*, 2012). The frigid highlands determine cold weather and limit regional economic activities; and we guess there are some relationships between harsh climate and local religious inclination. As similar as in the Xinjiang, the religion in Qinghai and Tibet has both positive and negative impacts on economic evolution and environmental protection. Because of the limitation of cultivation in this region, economic development is highly depending on natural grassland and mineral resources. Animal husbandry hence is the pillar industry until now. Worse than in the Xinjiang, climatic hazards on the Qinghai-Tibet Plateau lead to over 25% of livestock dead before being sold or eaten (Yin *et al.*, 2014). Regional industrialization even did not occur due to immigrations mainly for religious purposes, so that development of advanced technology was deterred. Emigration moved to the relatively low altitude fringes of the Qinghai-Tibet Plateau, and also took their religion and culture to the border regions of Sichuan and Yunnan Provinces. Moreover, Tibetan believe the Buddha and some unknown the Holy Spirit living at the snow covered peak of mountain, so they have never climbed up to the top, even never try to climb, and even to think about that is prohibited in their faiths. These thoughts from some mysterious religions form local esteem to natural resource and environment that to some extent protect ecosystems in many mountainous regions on the Qinghai-Tibet Plateau and the border regions of Sichuan and Yunnan; but also to some extent hinder innovative spirits of scientific exploration, and make outlanders are very hard to be allowed to invest business there. Interestingly, research studies about this region are much more than any other ecologically fragile regions of China, however, we did not find convictive evidence to prove positive relationship between research records and economic growth on the Qinghai-Tibet Plateau.

Local indigenous knowledge is distinctive and obvious. For instance, traditional housing structure has been inherited almost everywhere at Tibetan settlements. The architectural explanation of Tibetan housing has proved that their housing structures are climate adaptation (Zhang, 2008). The flat roof is for absorbing solar energy and keeping warm during night time; and, the edge of eaves and windows are piled with coloured wood for sheltering from rains, and these white or red coloured wood on the wall for striking people from the outside view. Because of the low production of agriculture, the most of Tibetan people eat mutton, beef, buttered tea and *zanba*; but local people do not eat the meet that was just slaughtered in a day, named *nyin sha*, because they believe every life has its soul which will leave in a day after it dead, so that they will eat them after a day past. Some of Tibetan living at the east of the Qinghai-Tibet Plateau do not eat fish, snake and frog also because they believe these animals are the embodiments of sacred dragons. Actually, that somehow protects biodiversity in the upstream Yangzi River. In addition, the convention of Tibetan funeral is celestial burial. In their folk custom, people only in upper class can be executed by celestial burial. After they died, their bodies will be cut into several pieces and transported to a specific 'holy' place to wait for wild vultures to eat them all. Specialist Tibetan monks take in charge of this ceremony in every day. We think these folk customs let Tibetan is a part of natural food chain to provision local biodiversity.

To respect of local religions and folk customs, exploration of natural resource on the Qinghai-Tibet Plateau is also restricted by some strategic development policies of the current Chinese government. This

shapes the region prone to developing tourist economy, but facing a slow urban growth and an increase of inequality of the quality of life between urban and rural residents. In those far rural regions on the Qinghai-Tibet Plateau, people still rely on pastoral and agricultural production with a low economic efficiency. Comparing to Tibet, Qinghai Province is trying to develop manufacture and absorbing investments in the Golmud City, we will remain concerns about this trend. To short summarize, economic evolution on the Qinghai-Tibet Plateau in documented Chinese history is somehow hindered by local religion and folk customs mainly due to geographic limitation and atrocious climate but obviously preserving regional environment and ecosystem.

5.5 *The Loess Plateau*

According to the record count of Google Scholar, there are near to 88% of records in category 1 including three combinations of key words in Table 7. The Loess Plateau suffers from climate changes in history severely, but is a typical region which has developed in western China successfully. The upstream and midstream Yellow River lie on the Loess Plateau. The upstream Yellow River after flowing down from the Qinghai-Tibet Plateau passes through the south of Gansu Province firstly. There were three times of large deforestation for reclamation in the Qin Dynasty (221–207 B.C.), the Ming Dynasty (A.D. 1368–1644) and the Qing Dynasty (A.D. 1636–1912). This leads to environmental degradation severely, having great impacts on water loss and soil erosion in south of Gansu and north of Shannxi, and also results in local people suffering from extreme poverty in modern history.

Economic evolution in this region has been influenced by mixed effects of cultural evolution in which local culture experienced three stages of development: culture-hindered, culture-mixed and culture-impelled. During the Wei-Jin Period and the Southern and Northern Dynasties (A.D. 220–589), regional climate was cold. There were social chaos with melees among vassal states. After the Tang Dynasty (A.D. 618–907) unified the all vassal states, Ancient China achieved the most prosperous period; interestingly, weather got warmer during that time period. Then, during the Five Dynasties and Ten Kingdoms (A.D. 907–960), climate in Ancient China became cold again, wars among vassal states occurred again (Ge *et al.*, 2014). We cannot reject that continuous wars occurred during cold periods that brought negative impacts on economic growth in history, and that also broke through cultural parclose among different ethnic groups. Typical provinces like the Ningxia was subordinate to Shannxi and Gansu Province in the Qing Dynasty (A.D. 1636–1912), and it became a province until 1957 since many *Huí* ethnic groups have settled down there. Because the Silk Road has been across Ningxia from the Eastern Han Dynasty, regional transportation has been developed which promotes commercial trade and cultural communication,

Table 7. Categorized Record Count of the Searched Word Groups about Loess Plateau on Google Scholar

Category	Search terms	Records	Percentage
1	‘economic evolution’ and ‘climate change’		
1	’economic evolution’ and ‘cultural’	101	87.8
1	‘climate change’ and ‘cultural transition’		
2	‘economic evolution’ and ‘economic base’	0	0.0
3	‘economic evolution’ and ‘location’	12	10.4
4	‘economic evolution’ and ‘natural environment’	1	0.9
4	’economic evolution’ and ‘resource endowment’		
5	‘economic evolution’ and ‘ruggedness’	1	0.9
	Total	115	100

so that mixed-culture has positive impacts on economic development. Skills of agriculture production and engineering of environmental management also push economic growth with technical innovation, such as making glass and planting some imported seeds including pepper, grape, pomegranate and carrot, etc.

Another case study region is Shanxi Province, which has been an important military prefecture since every dynasty of Chinese history, and even so-called the cradle of Chinese civilization. Cultivation culture was documented from ancient Yao time (2447–2307 B.C). According to the latest archaeological findings, researchers infer that the centre of the Yao time was in the south of Shanxi where was also the location of the centre of the Western Zhou Dynasty (1046–771 B.C.) in documented Chinese history. During the Spring and Autumn and Warring Stage Period (770–221 B.C.), Shanxi was occupied by the Jin State (632–349 B.C.), so that its abbreviation in Chinese is *Jìn*. As a rich region in history, population has increased there in two millenniums continually. Agricultural activities hence have huge impacts on regional environment. Soil degradation becomes to impede traditional cultivation. Droughts and plagues of pests even induced chaos and rebellion that consequently led to changes of dynasties (Dai *et al.*, 2009; Fan, 2010). Local people have to live on other business. Until the late of the Qing Dynasty (A.D. 1636–1912), there were many famous merchants holding a large business and formed a new trend of social ethos in mercantilism. They opened *Piào Hào* in large cities, which are similar to those present private banks to support small business, so that boomed national economy at that time.

This kind of pro-business culture actually restrains from environment degradation getting worse and drives economic growth efficiently. After those rich merchants went back to hometown, they built up large houses; thus, Shanxi is the province with the most ancient buildings in China. Even so, those rich people kept a simple living due to their traditional living style with the harsh weather in the past. People in the north of Shanxi eat processed *Avena chinensis*, potato and maize as their staple food because where mainly grow these kinds of plants due to the cold weather; while people in the south usually eat processed wheat, millet and maize. Miscegenation in history has not been limited that somehow facilitates cultural exchanges. Thus, economic evolution on Loess Plateau experienced three stages of cultural transition: culture-hindered, culture-mixed and culture-impelled. Even if the documented innovation records are less than about the Qinghai-Tibet Plateau, economic performance on the Loess Plateau is still higher than other regions in ecologically fragile regions of China because of those undocumented indigenous knowledge throughout cultural evolution.

6. Discussions and Conclusions

In ecologically fragile regions of China, climatic factors and natural geographical characteristics are constraints of economic evolution. In a process of social transformation, local culture adapts and shapes regional environment interactively and dynamically. Innovation throughout cultural transition has involved tremendous indigenous knowledge unpublished on journals or books. This forms traditions of local culture being inherited generation by generation. Genetic facts also illustrated climate adaptation within cultural transition in many species and human ourselves (Smith, 1987; Boyd and Richerson, 1988; Rehfeldt *et al.*, 1999; Rogoff and Ebrary, 2003; Klein, 2009; Boyd and Richerson, 2009; Richerson *et al.*, 2010; Ammerman and Cavalli-Sforza, 2014).

From the record counts in recent 200 years on Google Scholar, we search eight combinations of key word groups to examine economic evolution in each selected part of ecologically fragile regions of China. We find that the climate and culture are the main concerns; then the location ranking at the second place; the environment and resource are placed at the third place; the economic base is at fourth place; and the ruggedness is the lowest. These results match our assumptions that culture and climate are the most important to economic evolution in ecologically fragile regions in modern Chinese history. More interestingly, the number of research records in English which are supposed to symbolize endogenous innovation is not as much as the numbers of real economic performance in modern Chinese history. For

Table 8. Estimations of Innovative Knowledge in Five Categories on Real GDP in Ecologically Fragile Regions of China, 1993–2014

Variable		Code	Model (a) Coef.		SE	$P > t$	Model (b) Coef.		SE	$P > t$	Model (c) Coef.		SE	$P > t$
Dependent variable	real GDP	lngdp												
Independent variable	ARC	lnarc	−0.135		0.1021	0.189	0.207***		0.0639	0.001	0.207***		0.0639	0.001
	cultural and climate change	lncc	−0.512		0.4987	0.306	1.087***		0.3240	0.001	1.087***		0.3240	0.001
	economic base	lneb	−0.681		0.5782	0.240	1.206***		0.3703	0.001	1.206***		0.3703	0.001
	location	lnlc	1.094		0.9788	0.265	−2.072***		0.6314	0.001	−2.072***		0.6314	0.001
	environment and resource	lner	−0.226		0.2095	0.282	0.439***		0.1371	0.002	0.439***		0.1371	0.002
	ruggedness	lnrg	−0.041		0.0467	0.384	0.085**		0.0338	0.013	0.085**		0.0338	0.013
	first lag of real GDP	L1.lngdp	1.102***		0.0792	0.000	0.838***		0.0498	0.000	0.838***		0.0498	0.000
Dependent variable	ARC	lnarc												
Independent variable	first lag of ARC	L1.lnarc	0.984***		0.0141	0.000	0.291		0.2195	0.187	0.411***		0.1057	0.000
	first lag of real GDP	L1.lngdp	0.012		0.0071	0.106	−0.211*		0.1110	0.059	−0.311***		0.0535	0.000
	intercept	_cons	0.158*		0.0851	0.064	1.280		1.3232	0.334	4.849***		0.6374	0.000
			RMSE	R^2	*F*-stat	*P*	RMSE	R^2	*F*-Stat	*P*	RMSE	R^2	*F*-stat	*P*
		lngdp	0.0630	0.998	246295	0.000	0.0550	0.998	323031	0.000	0.0550	0.998	323031	0.000
		lnarc	0.0647	0.990	4806.7	0.000	1.0052	0.036	1.81	0.167	0.4842	0.259	16.92	0.000
Model (a)	Endogenous variables	lngdp	lnarc											
	Exogenous variables	lncc	lneb	lnlc	lner	lnrg	L1.lngdp	L1.lnarc						
Model (b)	Endogenous variables	lngdp	lneb											
	Exogenous variables	lnarc	lncc	lnlc	lner	lnrg	L1.lngdp	L1.lnarc						
Model (c)	Endogenous variables	lngdp	lncc											
	Exogenous variables	lnarc	lneb	lnlc	lner	lnrg	L1.lngdp	L1.lnarc						

Notes: *$0.05 < P \leq 0.1$; **$0.01 < P \leq 0.05$; ***$P \leq 0.01$.

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instance, higher economic outputs on the Loess Plateau with lower research records in English on Google Scholar, while, the Qinghai-Tibet Plateau has the lowest economic outputs with the most concerns from English world.

To further understand relationships between research records and economic development generally, we also analyse variants of dictators in study regions. By constructing panels, we test whether five categories of innovative knowledge have impacts on real GDP and the average resident consumption (ARC) during 1993–2014, and find some interesting results. See Table 8. In the base model (a), we assume final demand of individuals' consumption determines economic outputs over time; then in the model (b), historical endogenous knowledge of 'economic base' are assumed to be highly relevant to economic growth which drives economic outputs over time; and in the model (c), adaptive 'cultural' response to 'climate change' is assumed to be the dictator for economic growth of regional development. To analyse three models with the fewest bias and the least heteroscedasticity (Shonkwiler and Yen, 1999), three dictators are tested by two instrumental variables: first lag of real GDP and first lag of ARC. Estimations of three models by employing two-stage least square (2SLS) report that the adaptive 'cultural' response to 'climate change' determines real GDP as an engine of 'economic evolution' in the study regions. Therefore, it further addresses that a comprehensive understanding of the adaptive 'cultural' response to 'climate change' is determinate in ecologically fragile regions of China.

By elaborating previous research about study regions, we find that there are three stages of cultural transition in economic evolution in ecologically fragile regions of China. The Qinghai-Tibet Plateau and the Xinjiang region are culture-hindered adaptation in economic evolution to climate change in social transformation mainly due to traditional religions and distinctive folk customs. The Yunnan-Guizhou Plateau is culture-mixed adaptation in economic evolution mainly because multi-ethnic groups coexist under diverse climates in micro-watersheds. The Sichuan Basin is cultural-impelled adaptation in economic evolution to regional environmental change. There people migrate back and forth between mountainous and plain regions mainly for survival under variance of regional climate changes and the ruggedness of geographical conditions. The Loess Plateau has experienced culture-hindered and culture-mixed adaptation due to its important military location and long history of economic base. This forms a distinctive local culture which can self-impel technological innovation through advanced transportation induced multi-cultural communication. The cultural elements are the most important factor to the economic evolution on the Loess Plateau, which experiences all three stages of cultural transition under the limitations of climate changes and regional characteristics in social transformation. Thus, the real economic performance on the Loess Plateau is higher than the most of ecologically fragile regions in China even if research records in English are less than other regions on Google Scholar.

The implication of this study is that the English world has different preferences from Chinese native researchers which lead to lower research records of the Loess Plateau on Google Scholar. Another explanation is that indigenous knowledge throughout cultural evolution have already solved some real problems and have been applied in daily living before those are documented and published. This argument needs to be figured out in reviews of historical documents of a specific region.

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