

# Patterns for Sustainable Technological Innovation in Higher Education Institutions and Regional Sustainable Development

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**Abstract**--This paper presents the relationship between sustainable technological innovation in higher education institutions and regional sustainable development in the new normal of Chinese economy, by taking into account the variable of sustainable consumption. Although the role of sustainable technological innovation and commercialization of higher education institutions has been recognized as a significant contributor to the social development, the formation process of the sustainable technological innovation of higher education institutions, especially in a country in rapid economic transition, is not yet well reported in literature. After conducting extensive literature review and interviews to leading research groups in southern Chinese higher education institutions, the authors developed a Sustainable Technological Innovation (STI) model to provide guidelines for innovation in higher education institutions and regional sustainable development, with a focus on sustainable consumption. This model is also applicable for other emerging economies that are seeking for sustainable technological innovation in order to maintain sustainable consumption.

## I. INTRODUCTION

The higher education institutions have been broadly considered significant contributors in promoting regional sustainable development. Yet little is known about the operation of sustainable technological innovation mechanisms adopted by higher education institutions for sustainable consumption in the transitional economy of China. While traditional technological innovation research routinely attributes the regional sustainability to the commercialization of technologies and skills created by universities, how these technological innovations come to be realized and continue to be sustainable are rarely addressed. Consequently research fails to explain how higher education institutions actually build their sustainable technological innovation which fosters regional sustainable development in terms of sustainable consumption.

In view of such inadequacies, this study aims to develop a sustainable technological innovation model (STI) for the higher education institutions in the new normal of Chinese economy, so as to accelerate the regional sustainable development in terms of sustainable consumption. This is in line with the current demand of the Chinese context. The Chinese economy is in a dynamic process of structural transformation for sustainable growth instead of purely input and investment, diversifies its economy by innovation and distributes the social benefits more evenly. Under such circumstances, the Chinese government has particularly empathized the importance of domestic sustainable

consumption through the sustainable technological innovation in higher education institutions.

This paper first features technology and its impact upon a sustainable consumption by taking a closer look at the nature of sustainable development in terms of sustainable consumption. Then it reviews the patterns of technological innovation in higher education institutions and regional economy development and points out the inadequacies of the patterns. Next, the open-ended interview data collected from southern Chinese higher education institutions are presented and analyzed. Finally, based on the existing literature and interview results, the authors developed a Sustainable Technological Innovation (STI) model aiming at guiding the sustainable technological innovation in higher education institutions and regional sustainable consumption.

## II. LITERATURE REVIEW

### A. Technology and Sustainable Consumption

Humans needs to be harmonious with their environment and limited earth resources [1]. In recent years, the emerging countries such as China, have experienced rapid development in terms of economy and living standard. Simultaneously, human activities are changing the natural environment. Over the last century, the consuming of fossil fuels has increased the concentration of atmospheric carbon dioxide. The deterioration of natural resources and environment is the price to pay for the economic development, including the huge consumption of natural resources such as water, energy, the emission of environmental pollution, and the destruction of natural ecological system [2] [3] [4] [5] [6] [7]. "The depletion and degradation of a number of key natural resources have already constrained conventional development in some parts of the world [1]". In this context, many people rethink the consumption patterns and explore ways and means of solving problems.

Technology, on the one hand, changed the human consumption patterns in a variety of ways, such as transport, package and communication. It has brought great convenience to humans' life. Technologies can increase the resource productivity and efficiency which means the amount of value extracted per unit of resource, rather than technologies for increasing the resource throughout itself [8] [9] [10]. Moreover, technology can exploit a new or renewable energy resource thus promoting innovative renewable application [11] [12] [13]. On the other hand, Technology development has led to environmental pollutions which finally threaten human health and natures. For example, many environmental analysis reports point out humans,

particularly those in emerging countries such as China are consuming more resources due to the application of technology in than the earth can regenerate, and filling waste sinks at a more rapid rate than the earth can assimilate [14] and increasing emissions of SO<sub>2</sub>, NO<sub>x</sub>, CO, CO<sub>2</sub> and other pollutants into the air, water and land [15] [16] result in serious harmful to the environment and human bodies [12]. However, some researchers argue that humans can utilize the fundamental scientific, technical and industrial know-how to solve the pollution problems [17] [18]. “The deterioration of the environment produced by technology is a technological problem for which technology has found, is finding, and will continue to find solutions” [19].

Technology has helped us to improve the quality of life in terms of communication, working efficiency, physical disease, and so on. For instance, doctors’ diagnostics have been easier and more accurate due to the development of nuclear medicine technology. There is also no doubt that technology has changed the way enterprises do business, domestically and internationally, and improve the quality and efficiency of their day to day operations.

The above discussion reveals that technology has had a greater impact on humans than any other single factor in the history of the world. The role of technology is principally that of raising output from scarce resources, creating the new energy sources [20] [21] [22] [23], lessening environmental pollution [24] and improving the quality of life of humans [25] [26]. In other words, technology is an effective tool to realize the sustainable consumption.

### *B. Regional Sustainable Development in terms of Sustainable Consumption*

In the existent literature, there are some key words defining and characterizing sustainable consumption. “Saving Resource Orientation” refers to minimizing use of natural resources and toxic materials, or using the limited earth resources wisely or not in excess of what people’ need [27] [28] [29]. “Environmental Orientation” represents the choosing, using, and disposing of goods and services on account of environmental benefit, without causing damage and pollution to the environment or loss of function in natural systems [27] [28] [30] [31] [29]. “Quality of Life Orientation” addresses the demand side, not only focusing on the basic human needs, but also enhancing the quality of human life [27] [32] [31] [29] [33] or so-called achieving the well-being for people [34]. “Future Generation Orientation” means we have not to spoil the lives of future generation via protecting the natural system and resources [27] [32] [31] [29].

Sustainable consumption contributes to regional sustainable development in terms of reducing economic and environmental costs, strengthening the economic competitiveness, and reducing property [35]. The United Nation Conference on Environment and Development 1992 called for the “changing consumption patterns and thus reducing the environmental stress and meeting the needs of humanity” [36]. The term of sustainable consumption pattern

was introduced in this background [37] [38] [32]. At present, sustainable consumption is rapidly developing and popularizing in China as well. The central government and local authorizes pay great attention to sustainable consumption [39] [40]. In 2005, the State Council proposed the Scientific Outlook on Development and Strengthening Environmental Protection to promote the environmental friendly consumption pattern and the idea of creating conservation culture. The concept of sustainable consumption is still “no clear agreement either on a precise definition of sustainable consumption or even on the domain of application of the concept [38]”. Based on the definitions of UN, sustainable consumption and production is about promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all [35].

### *C. Technological Innovation in Higher Education Institutions and Economic Development*

Technological innovation refers to an iterative process initiated by the perception of a new market and/or new service opportunity for a technology based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention [41] [42] or industrial objective of enterprises [43]. Technological innovation is also widely recognized as the main driver of industrial growth [44] because the new technical skills and knowledge are generated [45]. Moreover, technological innovation provides the knowledge base or resource, scientific cognition, and decision making supports for humans to solve the problems encountered in development, and thereby promotes the economic growth and social development [46] [47].

In order to keep the technological innovation in higher education institutions, the innovation resources are indispensable components. Technological innovation requires an organization to have competences to accomplish something by using a set of resources such as culture, equipment, machinery, finance, and so on [48] [49] [50] [51]. The culture contributes to the creativity and innovation occur in an organization [52] [53] [54] [55]. According to the model of the influence of organizational culture on creativity and creation (Fig. 1), there are five determinants of culture related to creativity and creation.

This model shows that an organization should have innovation strategy with shared vision and mission based on innovation orientation and value of purposefulness. Except for strategy, organizations should build a flexible structure to support autonomy and cooperative teamwork spirit, which can promote the innovation and creativity [55]. Support mechanisms should also be built in an organization to create an environment that could promote creativity and innovation. Researchers and their teams are awarded for well-proven, trusted methods and fault-free work, and what is more, they should also be awarded for risk taking, experimenting and

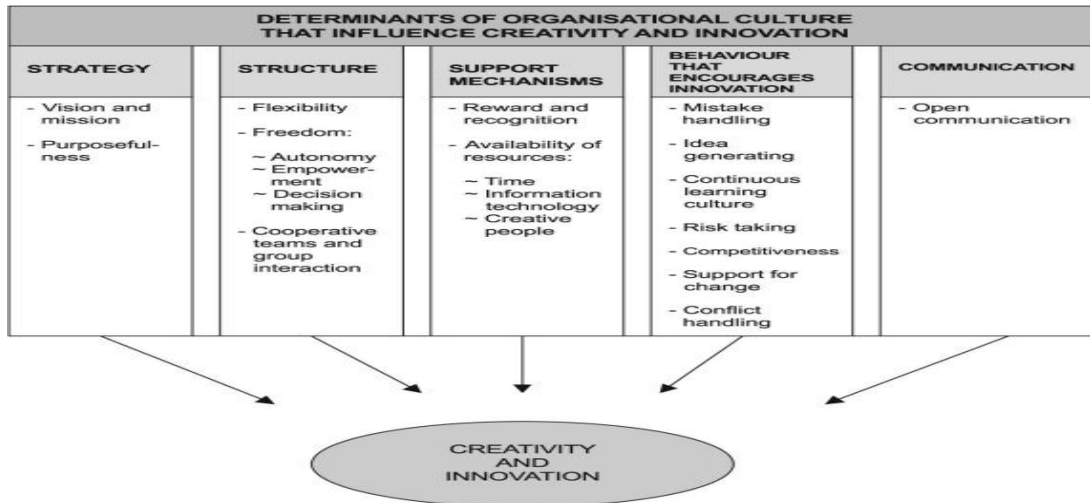


Figure 1: Influence of Organizational Culture on Creativity and Innovation [55]

generating ideas, and also be given the enough time to generate new ideas and working on their favorite projects [55] [56] [57]. Human capital is closely related to the creativity and innovation in higher education institutions. A creative personnel should be intelligence, knowledge, risk taking, inquisitiveness, and energy. People from different or diverse backgrounds could lead to the richer ideas that stimulate the process of innovation and creativity in an institutions [55]. Furthermore, organizations acknowledge failures, encourage to generate new ideas and take risk, build the learning and communication culture, reward the competitiveness, support change, and tolerate the conflicts and thereby promote the creativity and innovation [55]. In Chinese higher education institutions, the environment of freedom and autonomy is still relatively restricted compared with the environment in elite Western education. However, China's higher education institutions make progress step by step, particularly in science, technology, engineering and mathematics subjects [58]. The Changjiang Scholar's program was introduced in 1998 and "Recruitment Program of Global Experts" also can be called as "the Thousand Talents Plan" was initiated in 2008 with the aim of strengthening the research capacity of Chinese higher education system by attracting talents working overseas back to Chinese higher education institutions. In China, the increasing number of higher education institutions create the academic environment that is tolerant of failure and conflict encouraged by the central government [59] for the consideration of new information and ideas exchange and flow, thus encouraging the spirit of adventure and risk [60].

Besides culture, other resources such as equipment, labs, finance support on technological innovation should not be ignored. Years of pouring money and resources into its laboratories, wooing scientists home from overseas and urging researchers to publish and patent is starting to give China a competitive edge in technology, a strategic field it sees as ripe for "indigenous innovation". The vast resources

China can throw at research and development - overall funding more than quadrupled to \$191 billion in 2005-2013 and the Thousand Talents Program has repatriated scientists - allow China to jump quickly on promising new technologies, often first developed elsewhere [61] [62].

Finally, the results of technological innovation in higher education institutions are manifested through patents, books, articles, skills and so on, and can be directly used by the local enterprises thus improving the productivity and innovativeness of firms and promoting the regional economic development [63] via the commercialization process or so called technology transfer. On the other hand, the local enterprises can also get the human resources with innovation spirit from the higher education institutions. The higher education institutions serves as facilities which cultivate the human capital. They create human capital insofar as they educate the future workforce and endow employees with specific skills [64]. These innovative talents can enhance the local enterprise' technological innovation capacity and make better use of the limited resources.

#### D. Sustainable Technological Innovation in Higher Education Institutions

First of all, the existing literature on technological innovation mainly illustrate the importance of developing new technologies in terms of knowledge and skills on establishing a new production system with higher efficiency and thereby achieving the commercial or business values in enterprise thus promoting local economy development [65] [66] [67] [68]. In a word, the traditional technological innovation focuses on the economic benefits and people could ignore the protection of ecological environment and even in opposition to the natural environment to destroy the limited sources sometimes and thus hampering the implementation of sustainable consumption. The sustainable technological innovation philosophy takes into account environment, resources, and the needs of next generation and

promote the mutual support and development of humans, economy, environment, resources, and society [69] [68]. Thereby, there remain some differences in nature between technological innovation and sustainable technological innovation. In order to promote the “sustainability” in local consumption, the sustainable technological innovation orientation should be adopted by higher institutions.

Secondly, effective public and government policies or regulations can also contribute to the innovation and creativity behaviors except the factor of culture in institutions. China is currently in transition from high speed to medium speed and thus the associated reforms under the new normal economy have necessitated changes in the science and technology in order to maintain the economy development. China government issued a matching policy reforms on various aspects covering to stimulate the technological innovation in education and research organizations that are the main force in knowledge production activities [70] such as: R&D investment; support from the financial sector, technology importation, digestion, absorption and re-innovation; creation and protection of intellectual property rights; human resource development; innovation base and platform [71].

Thirdly, China higher education institutions have long been controlled by different levels of political administration. The system has been characterized by high levels of centralization. China higher education institutions have to obey the leadings from the state and lack the independence. Although the outline of China’s National Plan for Medium and Long-term Education Reform and Development 2010–2020 has been announced, the centralization has started to change to institutional autonomy step by step. Indeed, ‘semi-independence’ is an appropriate description of the Chinese situation. Higher education institutions are neither distinctively separated from the government [72]. In order to support the innovation activities, higher education institutions should be granted the greater autonomy so as to encourage the creativity.

In a word, in the new normal of Chinese economy, China policy leaders call for close coupling between science and technology and the social development, as well as the establishment of new mechanism in higher education institutions to the benefit of producing innovation fruits and converting these results to the local society, so as to realize connection between technology and economy, and increase the contribution rate of technology to the sustainable development in terms of consumption [73] [74]. Under this background, it is necessary to develop a Sustainable Technological Innovation (STI) model to provide guidelines for sustainable technological innovation in higher education institutions and regional sustainable consumption.

### III. RESEARCH METHOD

#### A. Data Collection Method

In order to find out to what extent the Chinese higher education institutions have conducted sustainable technological innovation for the regional sustainable development in terms of sustainable consumption, semi-structured interviews are conducted in this study. The authors choose interview research method because it is more concerned to understand the individual’s perceptions of the world [75]. An interviewer can also probe deeper and investigate feelings, and motives which a questionnaire can never do [76]. Semi-structured interviews on the one hand, have a structured overall framework, on the other hand, allow for greater flexibility within the framework [77]. However, it is critical to gather information on a one to one basis with the representatives in Chinese higher education institutions. This is because the ideas and attitudes on technological innovation by individuals vary from person to person.

The authors used semi-structured interviews as a ways of getting an insight of how the higher education institutions perceive the sustainable technological innovations or what they think in the context of the new normal of Chinese economy. Interviews carried out on a one to one basis will help the authors to be more aware of individual differences [77]. Moreover, the interviewers can design the interview in such a way that the interviewees give the type of information that is relevant. In this study, although the researchers remain in control of the direction the interview is taking, there is much more rooms for informants to give their own opinions or experiences about sustainable technological innovation in higher education institutions.

#### B. Data Collection Procedure

##### Step 1: Informants selection

Universities in southern China are taking the lead in an array of reforms aiming at making academic centers and scientific collaboration more international and more dynamic [78]. The authors invited representatives from the leading research groups in southern Chinese higher education institutions for their opinions toward the sustainable technological innovation. Two of them became informants of this study.

TABLE 1: PROFILE OF THE INFORMANTS

Informant	Position in Research Groups	Research Domain
Informant 1	Project Leader	Medical Research Center
Informant 2	Laboratory Researcher	Food Safety Research Center

##### Step 2: Interview sessions

The interview sessions with the two informants were carried out three times by using Skype and lasted about 30 minutes each time. The informants were briefed and given the interview plan as well as the framework of study in advance.

IV. RESULTS

Informant 1

Informant 1 is a Project Leader in a Medical Research Center in southern China. His main task is to research and develop new medicines. He was recruited to join the research institute 5 years ago. Since then, he has been working at the medical research institute and experienced the changes of technological innovation at the institute. Therefore he has been considered as the best candidate to interview. Below is what the informant has told the interviewer about what the research group does in order to keep sustainable technological innovation and thereby support the local sustainable development and consumption.

The informant 1 stresses the importance of innovation in the institute since the beginning of its foundation, the institute has never shifted its focus away from doing natural science. In order to promote innovation, the institute has offered all kinds of support, such as providing funds and staff, to encourage the researchers to give a full play in their technical fields to make progress in scientific and technological study. Achievement of scientific research were also linked to promotion of the staff.

TABLE 2: (SUSTAINABLE) TECHNOLOGICAL INNOVATION IN INFORMANT 1'S INSTITUTE

Informant 1	Basic beliefs related to Technological Innovation	Technological Innovation in the new normal of Chinese economy
Project Leader	<ol style="list-style-type: none"> <li>1. Support from top management and administration teams</li> <li>2. Promotion/ Reward</li> <li>3. Research Enthusiasm</li> </ol>	<ol style="list-style-type: none"> <li>1. Sustainability</li> <li>2. Communication with stakeholders</li> <li>3. Innovative culture</li> </ol>

The informant 1 is very proud of the remarkable success that his medical research center has achieved. When we asked about an example of technological innovation, he gives the following words:

*With the researchers' continuous efforts, we have achieved remarkable success in medical research, especially in the area of combining traditional Chinese medicine with the Western medicine, and gained many rewards.*

This clearly shows that Informant 1 believes in giving the researchers the support to exercise their initiative ideas in technological innovation. That is to say, innovation is not just a new concept from his perspective. The institute has always attached importance to it. From the onset, with researchers being given the support and rewards to take the initiative in the medicine innovation, it can be said that there is close relationship between supporting system and technological innovation. However, to what extent, compare with the past, is there any breakthrough in terms of the intension or substance of the technological innovation in the new normal of Chinese economy?

The Informant 1 admits there have been some changes of the requirement for scientific study from the institute. Specifically, in the past, the researchers in the institute would be satisfied with things like whether the results of the research can be published in some core periodicals and the citation rate of the papers. However, in recent years, higher standards are set up. the research should be directed to the most common diseases in the local area, the results of which would benefit the local people, i.e. to improve the life quality and lower the medical expenses. The following are the quotations from the responses:

*As we all know, due to the natural environment and climate, there are different high incidents of diseases in difference areas that would greatly affect people's life in that area. To diminish the hurt and damage caused by the disease, we have been focusing on developing new drugs and working with the hospitals and drug companies to expedite the process of getting the new drugs on market so as to benefit the patients.*

The Informant 1 also highlights the new requirement of the institution on research and development activities, the researchers need to use resources more efficiently without sabotaging the environment in order to keep the research work continuously in a healthy way. This indicates the difference of technological innovation that existed in the "new normal" economy development situation. The essence of technological innovation at this institute has shifted to reflect the substance of sustainability, meaning using limited resources more efficiently without damaging the environment in a sustainable way.

From the sustainability point of view, the Informant 1 was asked to list the technical innovations the research group has achieved. The Informant explained the current research direction:

*Traditional Chinese medicine is rich and profound. It has obvious curative effect on some chronic and stubborn diseases. In our research, we laid emphasis on finding the effective ingredients in drugs. Combining traditional Chinese medicine with Western medicine, we have developed some new drugs, which have achieved good result in clinical trials. This in turn aroused our spirit in the research work.*

From the response, the interviewer finds out an interesting evidence. In order to let the research result be used in practice more quickly, the research group changed the personnel structure. In the past, the staff of in the group is formed with mainly the students from the medical institute. Headed by the professors, they worked together to complete the new drug development. Now, the team has been extended broadly. Except for the medical students, the staff now include doctors from the university hospital and representatives from the drug companies working together for years. The advantage of this is to strengthen and smooth the communication throughout the whole process, from research to manufacture, and then to clinical practice. Researchers can make modification and

improvement of our research results through feed-backs from the drug companies and the hospital, which would be more efficient than the close-door study. This clearly shows the importance of open communication between researcher groups and stakeholders in the sustainable technological innovation process.

The interviewer is also interested in the measures of top management adopted in fostering sustainable technological innovation. The Informant 1 explains there are great changes in the institute, especially in the entire atmosphere. The institute encourages researchers to challenge and break through the old tradition, to be more creative and innovative. In the beginning, the researchers were hesitating with carrying out this new concept, for the traditional Chinese culture demands respect to teachers and authorities without challenging them. However, they found in the institute, many measures have been adopted to encourage creativity and innovation. For instance, young researchers are given more freedom and room in their research, without being restricted by the professors. The institute would provide support in funds, labs and equipment to those projects that aim at improving the life quality of the people and the applications for the projects would not be limited to the senior staff. These measures have inspired the morale of the younger researchers. The team leaders are also very supportive. Whenever young researchers encountered failure or setbacks, they would express their understanding as persons with past experience and with comfort. Informant 1 really feel that the environment for research work is open and favorable. Besides providing funds, labs and equipment, the institute also offers other supports to encourage innovation. One example is that the institute has built up relationship with some foreign research institutes and set up a platform for researchers to share resources with each other. Young researchers can now get the cut-edge information. This indicates that the successful sustainable technological innovation depends largely on an innovation culture in the organization.

The interviewer also get the information that the staff are being given more career opportunities due to the cooperation with hospitals and drug companies. For staff working on the front line, they can choose to have trainings in the cooperative drug companies, or in the university hospital, as long as it fits them. This is a great progress in the new normal economy, thus the sustainable technological innovation model should include not only new skills, patents, technologies, books, and articles, but also the cultivation of innovative human capitals so as to promoting the local sustainable development.

Informant 2

Informant 2 is the lab researcher in a Food Safety Research Center. His main duty is to participate in the food safety research and development. He joined the research group 7 years ago. Therefore, he has experienced the changes in Chinese consumers' attitudes toward to the food safety issue after the outbreak of toxic baby milk powder in 2008 and been considered as the best candidate to interview. The

informant told the interviewer what the research group does in order to keep sustainable technological innovation and thus provide a good quality of foods for local consumers.

TABLE 3: (SUSTAINABLE) TECHNOLOGICAL INNOVATION IN INFORMANT 2'S INSTITUTE

Informant 2	Basic beliefs related to Technological Innovation	Technological Innovation in the new normal of Chinese economy
Laboratory Researcher	1. Support from the top management 2. Research Enthusiasm	1. Sustainability 2. Communication with stakeholders 3. Innovative culture 4. Administrative support

The informant 2 also stresses the importance of innovation in his institute. Food has always been a concern for everybody, especially in recent years, when food safety becomes an issue. The Department of Food Study was set up with the founding of the university. The research in the department specializes in studying food additive, food packaging and food sanitation, etc. With decades of development, the institute becomes very strong in research work of the food industry. The Informant 2 illustrates the university has always stressed on innovation in the development of food industry and encouraged researchers to make more achievements in this field so as to help the economic development of the local area. In view of this, the situation of Informant 2 is similar with Informant 1 that innovation is not a new concept to them as they have always laid stress on scientific research and innovation and get the assistance from the top management.

However, after the incident of toxic milk powder, the concept of innovation has changed in the area of food industry. This is because safety of the food has drawn attention of more and more people now. The following quotations are given by Informant 2:

*Under such circumstance, a food safety study group was set up in our institute. This group is not only affirmed by, but also gained support from the university. The university helped us build up cooperative relationship with relevant departments of the local government, such as the Department of Quality Control, Department of Agriculture, and Department of Public Health. Our target is to more effectively guard the local food safety with our research results.*

The innovation in food industry is not only aiming at obtaining commercial opportunities, but also at providing the safety foods to protect the local people's health. Meanwhile, the group is now searching on producing new materials for food packaging and tableware out of the waste. This research aims to make use of the waste and transfer them to valuable material, which may bring potential commercial value and business opportunities, and protect the natural environment as well. It clearly demonstrates the development of technological innovation shift from the economic orientation to the sustainable orientation.

In regard to sustainability, the Informant 2 says:

*First of all, we need to set a high starting point. After all, food safety is of vital importance to people's health. It will affect health of this generation as well as the next generation. The poisoned baby milk powder disclosed in 2008 seriously harmed some children's health. Nothing is minor concerning food safety. Therefore our study and research will keep going on.*

When he was asked to list the technical innovations the research group has achieved, the informant said that new research is related to the application of fruits. The institute located in southern part of China where fruits, especially wild fruits are abundant. Through research, the team found that these fruits contain rich vitamins, polyphenols, anthocyanin, and water-soluble fiber, which are all helpful for the body's functioning. Drinks made with extracted juice from these fruits are suitable for people of any age group, old or young. Results of this study are beneficial in many ways: making full use of local natural resources, helping the local economic development, increasing people's income, and improving people's health condition. These are all based on the research. For this study, the team built labs with all needed equipment. After numerous experiments, the researchers finally found the best solution.

From the communication with Informant 2, the interviewer finds out there is a close relationship between the institution and local enterprises. Just like he described:

*We attach importance to the application of the technical innovation. Our institute has cooperative relations with many local enterprises, and our patents have been commercialized into production by many manufacturers.*

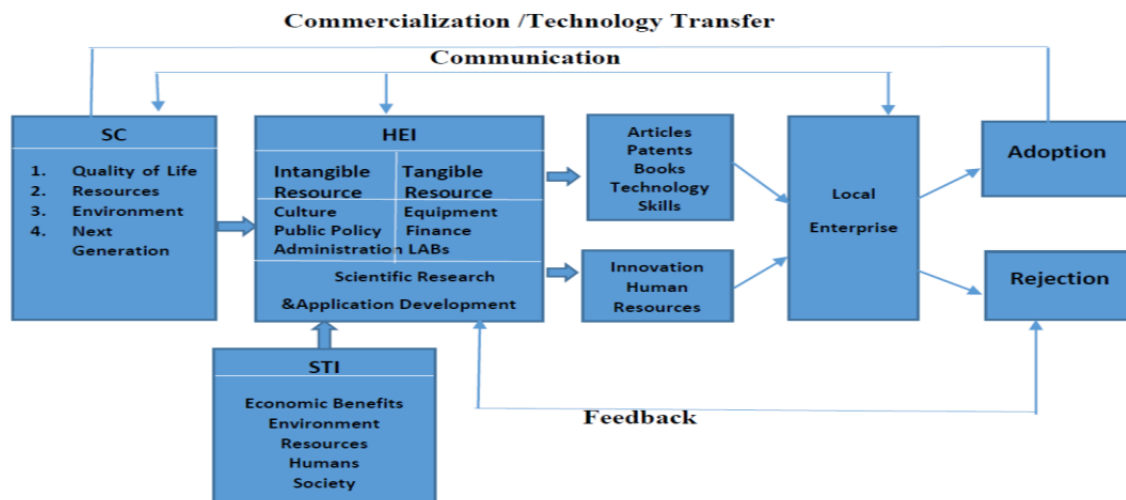
The informant 2 highlights the importance of communication with stakeholders as well. If the products are not recognized or when problems of the products are found in the market, research team will get feedback from the manufacturers, and researchers can make improvements

promptly. In this regard, communication with enterprises and manufacturers is important to research.

The informant was also asked to answer whether there are any specific measures from the university level to support sustainable technological innovation? Fund support is essential to scientific research is no suspense. The university has always taken research on food technology as a very important part of its work. The department received funds from both university and the local government and then purchased equipment and built up the labs for experiments, which provide the basic condition for scientific research. Besides that, the department also set up cooperative relations with universities in other countries. The department learned a great deal from them through cooperation and also from the experts invited to the institute. It clearly indicates an innovative atmosphere in terms of open and communication is to encourage scientific research and creativity. The informant 2 also explains the importance of the administrative departments in the process on innovation:

*All the administrative departments of the university also offered us the needed assistance, such as simplifying and expediting procedures of applications for funds, space, and equipment. This is undeliverable several years ago, when the administrative staff were very bureaucratic and many researchers complained of the lack of communication with them. Now, our institute organizes the weekly round table meeting including the first line researchers and administrative staff and thus creates an open communication environment to share information and solve the research problems together.*

After interviewing the representatives in higher education institutions in southern China and reviewing the relevant literature on sustainable consumption, technological innovation, and the new normal of Chinese economy, the authors develop new patterns of sustainable technological innovation as follows (see Fig. 2).



SC: Sustainable Consumption;  
HEI: Higher Education Institutions;  
STI: Sustainable Technological Innovation

Figure 2: Sustainable Technological Innovation (STI) model in the new normal of Chinese economy



## V. DISCUSSION AND CONCLUSION

Higher education institutions are mostly considered significant contributor not only to the promotion of local economic development but also to the pursuit of regional sustainability. The research objective of this study, i.e. *to set up new pattern of Sustainable Technological Innovation (STI) in higher education institutions, so as to accelerate the regional sustainable development in terms of sustainable consumption in the new normal of Chinese economy* has been achieved so far by an extensive literature review and semi-structured interviews on southern China higher institutions.

The establishment of new pattern of sustainable technological innovation in higher education institutions reflects the requirement of China's new normal economy, which pursues the sustainable consumption on the basis of sustainable technological innovation in the higher education institutions. The sustainable technological innovation, on the one hand, depends on the support of tangible innovation resources such as equipment, laboratories, and funding. On the other hand, it has to rely on the establishment of sustainable innovation culture, policy and administrative team to support the scientific research and application toward sustainability. The characteristics of innovation culture should consist of freedom, equality, openness, adventure, cooperation, creative human capitals, and so on. With the support of effective and sufficient resources, the scientific research and application development in higher education institutes should follow the sustainable idea and take the sustainable development path. Higher education institutions through sustainable technological innovation not only provide the specific knowledge, skills, patents, and etc. which will be adopted by local enterprises, but also bring a large number of talents for local enterprises and society, which promote the sustainable development in these enterprises. Through technology transfer, new products and services are developed and exploited, so as to promote the regional sustainable consumption. In the new pattern of sustainable technological innovation, the communication between higher education institutions and stakeholders is very crucial. The local enterprises can give the feedback to the institutions, which are valuable experience for future innovation.

The research results reveal that technological innovation in China higher education institutions in the new normal economy is more likely emphasizing on sustainability rather than purely economic factor, as has shown in the for-profit organizations. For example, the informant 1 illustrated the research orientation of new drugs is to improve the local people's life quality and lower the medical expenses through using resources more efficiently without sabotaging the environment thus keeping the research work continuously in a healthy way. The informant 2 argued that China food industry is not only aiming at obtaining commercial opportunities, but also at providing the safety foods to protect the local people's health. The intangible innovation resources such as innovative culture, policy, and administrative team

lead to generally better sustainable technological innovation rather than resources provided via tangible means such as fund, lab, and equipment. After interviewing the representatives in leading research groups in southern Chinese higher education Institutions, this study also reveals that the communication between higher education institutions and stakeholders should also be considered as the crucial element to enhance the capacity of sustainable technological innovation in terms of scientific research and application development. Besides that, higher education institutions have the potential to provide specific knowledge, patents, skills, articles, books, and etc. which can be transferred into the new products or services through commercialization process conducted by local enterprises so as to accelerate the sustainable consumption. Their role in cultivating innovative talents who can be regarded as the valuable human capital with innovative spirit in local enterprises should not be ignored.

## VI. LIMITATIONS AND FUTURE RESEARCH

It has to be admitted that this study has focused in particular on two higher education institutions in southern China. The higher education institutions have adopted the sustainable technological innovation pattern and defines themselves as being responsible for helping the local consumption to become more sustainable. There is a need to expand the sample size and do more empirical research to support the new pattern model on the sustainable technological innovation in higher education institutions that support sustainable consumption in emerging countries in transition.

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