International Journal of Development and Sustainability
Online ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 1 Number 2 (2012): Pages 145-170
ISDS Article ID: IJDS12083104

Benefits of agricultural technology innovation capacity to peasant farmers in rural poor areas: The case of DBN-Group, China

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Abstract

DaBeiNong (DBN) Technology Group Co Ltd is a private enterprise, at the cutting edge of the agricultural high-tech industry in China. It has developed its innovative capabilities through Research and Development (R&D) activities, skilled R&D personnel, new products, services, processes and markets. This study contributes to knowledge by identifying and constructing a model of the enterprise innovation capacity; the inputs and outputs of innovation in DBN and 9 other agricultural high-tech enterprises in China. We analyzed the enterprise technology innovation capacity and offered recommendations. Two sets of questionnaires were used; for the peasant farmers, and for the agricultural enterprises. We used the rank factors on an ordinal scale and simple percentages. We used econometric model to analyze seven factors of agricultural enterprise innovation capacity. The results show that R&D is strategic to Agricultural Enterprise Innovation Capacity (AETIC). However, the benefits to the peasant farmers need to be further intensified, and stepped up from its present average level. We found that enterprises with higher capital and larger sales have more R&D investment than those with smaller sales. Promoting agricultural research and rural development is crucial to pro-poor growth, given the potential for smallholder agriculture to rapidly absorb and adopt innovations.

Keywords: Innovation capacity, R&D, Innovation model, Commercialization, Innovation benefits

Cite this paper as: Eneji, M.A., Weiping, S. and Ushie, O.S. (2012), "Benefits of agricultural technology innovation capacity to peasant farmers in rural poor areas: the case of DBN-Group, China", *International Journal of Development and Sustainability,* Vol. 1 No. 2, pp. 145–170.

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1. Introduction

The development of agriculture and agricultural extension services in China have been subject to government interventions which, in turn, affect technology innovation. Socialism with Chinese characteristics has provided larger markets for private innovations, (Hu et al., 2011). The government's first policy document for 2012 underscores the importance of agricultural science and technology innovation, with the emphasis on advancing technology. Agricultural production methods have changed significantly. The related processes of industrialization and commercialization, product differentiation and increased vertical integration of the sector have raised new issues and challenges for the enterprise and the small-holder farmer. The peasant farmers in rural poor areas need to afford and adopt innovation for increased productivity, food security and higher income. As local governments find it increasingly difficult to attract and retain talent in rural areas, agricultural technology innovation is an alternative strategy for avoiding a potential food crisis of the future. Enterprise science and technology innovation capacities are the power tools behind rural economic transformation in developed countries. China's annual grain output increased from over 446 million tons in 1990 to 570 million tons in 2011. Over this period, advancement in hybrid seeds, pesticides and fertilizers played the major part of this growth (Li et al., 2009). However, while scientific and technological innovation benefits the society at large, the peasant farmers in poor areas are yet to benefit adequately, due to the high cost of adoption. The cost increases as technology advances. Government policy support needs to target more at the micro level. At the micro level, farmers who own more agricultural machinery or invest more in biochemical technology will have better harvest and income. Thus, the structure and competitiveness of the enterprise is affected by its innovation capacity.

Loss of agricultural land to infrastructure, urban and regional air pollution, e.g., tropospheric ozone and acid deposition; and climate change – changes in temperature, precipitation, sea level, extreme weather events such as floods, droughts and heat waves represent a major challenge, especially in the tropics and sub-tropics, where hunger is prevalent today. Crops, forests, livestock and fisheries are all projected to be impacted, most negatively. Hence, advances in AETIC are needed to develop temperature, drought, pest and salinity tolerant crops and trees, and address the issue of emerging animal diseases. AETIC is further driven by competitive market structure, food crisis (decline in food quality and quantity), and environmental challenges. Other factors are science and technology, politics, infrastructure and welfare reasons. Economic globalization has provided both opportunity and threat to the agricultural enterprise. Enterprises that do not have a strong innovation capacity may not afford to optimize their resources and remain competitive. In China, the specialization and commercialization of agricultural production has made the enterprise and farmers more aware of the importance of science and technology innovation, and hence its demands have widely emerged in the rural areas. The agricultural enterprise innovation capacity builds several linkages; within the enterprise, the industry, the domestic and international markets, the peasant farmers, and national development. The enterprise may find this study useful in terms of its decision making on new markets and evaluating its innovation capacity. It also brings to the awareness of the peasant farmers in rural areas, of the need to adopt innovation for higher productivity.

Agricultural technologies have achieved enormous yield gains as well as lower costs for large-scale farmers in developed countries. However, it has not solved the social and economic problems of the poor in developing countries, who have generally benefited the least from this boost in production. Besides, China is increasingly having less favorable environmental factors for agriculture such as drought, heat, ice and flood. Other factors working against reliance on traditional farming are the characteristics of urban-rural dual economy, loss of farm land and labor to urbanization and increasing demands for industrialization. China's current farming technology still lags behind that of the developed countries such as the United States, Japan, and Europe. And that's largely because of three major impediments: Firstly, there are not enough new technological and innovative results. Secondly, technology is not promoted enough in rural areas. And finally, there is a great lack of technological personnel in the agricultural sector. Presently, more than half of the country's pork, chicken and dairy supply, as well as over 90 percent of specialty vegetables, fruits and flower varieties, are reliant on imports, which is not sustainable. Food security in China is now a matter of national security. The changing agro-economic scenario drew attention of researchers on diffusion of technological innovation in agriculture. With fast increasing pressure of population, urbanization and industrialization on agricultural land, old methods and techniques of farm production cannot cope with the growing demand. Consequently, technology innovation and commercial crops are adopted to develop agro-economy, (Singh and Ashraf, 2012). Given the predominant role of peasant agriculture in rural economic transformation and the serious situation of enterprise technology innovation capacity-benefits for the peasants, it is very necessary to investigate the innovation capacity and the benefits for peasant farmers in poor areas. The questions posed by this study are: What factors influences the agricultural enterprise technology innovation capacity? What are the inputs and outputs of the AETI? What are the benefits of AETIC to the peasant farmers and to the enterprise? Other studies focus on the macro analysis of enterprise innovation capabilities (Gao and Zhang, 2011). While most of these previous studies have focused on the innovation capabilities, little attention is paid to the benefits to peasant's farmers in poor areas.

Our objective was to determine the input--output of AETIC, and the benefits for peasant farmers, as well as for the industry, in a model.

Alston et al. (2010) modeled panel data of state-specific United States agricultural productivity for the period 1949–2002 as a function of public agricultural research and extension investments. Their specific estimates of benefit-cost ratios were somewhat sensitive to modeling choices, but the general findings were driven by fundamentals. Specifically, the annual value of agricultural productivity gains is worth many times more than the annual value of expenditures on agricultural research. According to a research study, technological innovation contributed more than 40 percent of the economic growth rate in China during the period 1981-2000 (Fan and Watanabe, 2006). Wassily Leontief, developed strategies for the industrialization of Florida citrus industry to the benefit of small citrus farmers through the control of distribution and processing. Also developed, was the strategy for the industrialization of the US wheat-to-consumer chain as well as soybean market for animal feed. The benefits were agricultural efficiency, commercialization and economy of scale. Starting with the development of commercial hybrid double-cross seed corn varieties by the public sector in the 1930s, the private sector has assumed an increasing role in genetic improvement and seed reproduction in developed countries (Alston, 2010).

The Rockefeller and Ford's Foundations funding in the 1970s had significant impact on the transformation of American agriculture into more efficient factory farms or corporate agriculture. This has had global influence on developing nations' agricultural policies, agricultural technology innovation, agribusiness, and food security. For example, the International Institute of Tropical Agriculture's (IITA) development of improved maize varieties in the 1980s led to the transformation of maize production in the northern Guinea Savannah. Its work on the development of the improved soybeans varieties helped to make Nigeria the largest producer of soybeans in Africa. IITA biotechnology program saved ECOWAS region an estimated $94 million per year over the last 18 years. In Benin, Ghana, and Nigeria, the economic benefit of IITA innovation is estimated to reach over $2billion in the next fifteen years. With its America innovation capacity, IITA partners with national research institutes in these countries to tailor innovation according to national realities. The twin challenges of food security and climate change were discussed at the World Summit on Food Security Rome, November 2009 and the UNFCCC COP 15 Copenhagen, December 2009, (FAO 2009; World Bank 2009). The major benefit of agricultural technology innovation is to reduce poverty, greater food availability and lower food and input prices for all, (Janvry and Sadoulet, 2002). Porter and Stern (1999), defined innovation capacity as: the strength in transforming knowledge into new products, processes, and services. AETIC involves more than just science and technology. It involves discerning and meeting the needs of the farmers appropriately. At the micro-level, within the context of the enterprise, research and development is seen as enhancing enterprise's capacity to innovate, to absorb and make use of new knowledge of all kinds (US Bureau of Census 1998 and 1992; Statistics Canada, 1988 and 1992/93; Australian Bureau of Statistics, 1993). The innovation processes include the opening of a new market, the conquest of a new source of supply of raw materials or semi-manufactured goods, or the re-organization of an industry. In addition, enterprises differ in their ability to recognize and exploit technological opportunities.

Agricultural technology innovation has made it possible to introduce the genes that control the desirable traits into plant and animal strains with far greater precision and control than conventional methods (Pinstrup-Andersen and Pandya, 2001). Chemical; fertilizers, pesticides, and herbicides—have made a difference, bringing a newer class of extremely useful production inputs to agriculture. Also, an impressive array of improved crop varieties, the achievements of hybrid corn, rice, cotton, wheat etc are classic examples of success, (Moschini, 2001). DBN Technology Group innovations are embodied in the hybrid seeds, feeds and chemicals (pesticides, herbicides, insecticides and fungicides). Investment in the development and large scale adoption of high yield varieties (HYVs) such as hybrid rice, corn and wheat boosted agricultural growth and food security (Li et al., 2009). Poverty reduced rapidly and rural incomes doubled between 1978 and 1984 (Fan et al., 2006). In 1979, China's patent on hybrid rice developed by Yuan Longping was the first agro-technology patent registered to China in the United States. The Chinese lead in hybrid rice forms a significant share of the competitive advantage of China's nascent agribusiness corporations. From 1994-2001, the monopoly of agricultural trade by state agencies ended and agricultural trade was opened up to the private enterprises with increased market access. The private sector is playing a significant role in generating and providing agricultural technologies for the farmers. The private sector has also been actively involved in agricultural research financing. However, private commercial agricultural research is still relatively minimal, compared to the public sector investment. According to Bao (2010), enterprise technology innovation capacity is market-oriented, aimed to enhance enterprise competitiveness. The output of new product or new services is produced through Research and Development (R&D), technology transfer, sharing patent, technology diffusion and technology absorption. Similarly, Chen et al. (2010) established enterprise technology innovation index system in the iron and steel company in China which include: the technology product, the market, the finance, the environment, the policy, which all makes for the economic and social efficiency.

2. Methods

In the literature, several authors (Chen et al., 2010; Jiang and Fan, 2003; Wang, 2007) have used the matrix to analyze the innovation index, and explain which factor is the best decision variable for the enterprise. However, we consider most of these analyses did not account for peasant benefits and were rather too abstract for simple understanding. We chose to use econometric input-output model to analyze these input-output factors of agricultural enterprise innovation capacity. Agricultural Enterprise Technology Innovation Capacity (AETIC) is a process which combines certain inputs to produce outputs. The factors influencing agricultural enterprise technology innovation capacity are divided into input factors and output factors. The benefits which farmers get are part of the output of innovation. The other parts of the outputs are benefits to the enterprise and national development. We compared the quantitative analyses to find out which factor is most significant within and without the enterprise.. Since DBN has a bi-annual Science and Technology Achievements Awards (DBN STA), we decided to compare the latest STA in 2011 and the former in 2009, to determine the innovation capacity and benefits. Increased technology innovation capacity is broadly defined to include significantly improved or new processes, new markets, new products, services, adoption of improved agricultural practices, crop varieties, inputs and associated products such as plant and animal diseases controls within the two awards periods in 4 years (2008-2011). We attempt to evaluate the socio-economic benefits of DBN innovation to the enterprise and the peasant farmers. We use the rank factors on an ordinal scale, first ascertaining whether a factor is relevant or not for technology innovation, (0= not relevant and 1= relevant), then running from 1 representing fairly important to 5 representing very important.

Questionnaire was administered to farmers in two provinces-Fujian province; (Zhangzhou and Longhai) and Shanxi Province (Xiangyang and Sanyuan), respectively, and enterprise staffs in 10 agricultural companies were used to evaluate the AETIC and its benefits to farmers and the enterprise.

Modified from the Leontief production function, the factors affecting enterprise innovation are used in technologically predetermined proportions, as there is no substitutability between these factors. This function is of the form:

$$Y = \text{Min}\ (Q1/A,\ Q2/B,\ Q3/C,\ \text{-------}Qn/n) \qquad (1)$$

Where Y is the output of innovation,

Q1, Q2, Q3-----Qn are the utilized quantities of innovation inputs 1, 2, 3, ---- n respectively, and are technologically-determined constants; A, B, C----n are the ratios of the quantity of inputs.

Put differently in equation form:

$$AETIC=F(R\&DEX, NNPM, NOP, SRG, R\&DP`, NI, GPS) \quad (2)$$

Where:

R&DEX= Research and Development Expenditure

NNPM= Number of New Products to the Market

NOP= Number of Patents

SRG=Sales Revenue Generated

R&DP=Research and Development Personnel

NI= Net Income, and

GPS= Government Policy Support.

GPS is expressed as 1 for the presence of, and 0 for the absence of.

In the Sales forecasting and cost analysis, there is a statistical relation between the enterprise technology innovation capacity and the sales and costs advantages. The higher the innovation capacity, the enterprise enjoys economies of scale, reduced costs, increased affordability by the peasant farmers, higher sales revenue and benefits innovation.

Equation (2) is transformed thus:

$$Y= \beta 0 + \beta 1R\&DEX + \beta 2NNPM + \beta 3NOP + \beta SRG+ \beta 5R\&DP + \beta 6NI + \beta 7GPS + \mu \quad (3)$$

$$RD = f\ (AETIC) \quad (4)$$

Where RD= Rural Development

The primary objective is meeting farmers' need in added value, increase their income and productivity at minimum cost. This target will increase farmers' demand for enterprise technology innovations. With effective demand and property rights protection, the increased supply of enterprise innovation means profitability for the enterprise. The 10 companies sampled are compared and ranked in table 1. From the results, we chose the first two to run the regression.

3. Regression results from the innovation survey

- Monsanto Regression Results
- DBN Tech. Group Co. Ltd. Regression Results
- Equation 1. Monsanto

Dependent Variable: AETIC

Method: Least Squares

Date: 07/15/12 Time: 16:24

Sample: 1 11

Included observations: 11

	Coefficient	Std. Error	t-Statistic	Prob.
C	21.05585	467.0965	0.045078	0.9669
RDEX	0.332914	0.335591	0.992023	0.3943
NNPM	-5.737616	65.94420	-0.087007	0.9361
NOP	-3.932880	71.75382	-0.054811	0.9597
SRG	-0.032025	0.066120	-0.484346	0.6613
RDP	-0.052659	0.228976	-0.229976	0.8329
NI	0.132488	0.161601	0.819847	0.4724
GPS	19.78847	279.2649	0.070859	0.9480

R-squared	0.599427	Mean dependent var	146.0000
Adjusted R-squared	-0.335242	S.D. dependent var	175.6195
S.E. of regression	202.9330	Akaike info criterion	13.61889
Sum squared resid	123545.4	Schwarz criterion	13.90827
Log likelihood	-66.90390	Hannan-Quinn criter.	13.43648
F-statistic	0.641326	Durbin-Watson stat	3.250153
Prob(F-statistic)	0.717668		

- Equation 2. DBN Technology Group Co Ltd

Dependent Variable: AETIC

Method: Least Squares

Date: 07/15/12 Time: 16:49

Sample: 1 12

Included observations: 11

	Coefficient	Std. Error	t-Statistic	Prob.
C	-37.42847	467.5285	-0.080056	0.9412
RDEX	0.388177	0.353152	1.099178	0.3520
NNPM	25.27954	80.59788	0.313650	0.7743
NOP	22.00005	60.99813	0.360668	0.7422
SRG	-0.076299	0.118521	-0.643759	0.5656
RDP	-1.321758	1.084753	-1.218488	0.3101
NI	-0.006697	0.178804	-0.037455	0.9725
GPS	-51.17594	354.3810	-0.144409	0.8943

R-squared	0.449392	Mean dependent var	146.0000
Adjusted R-squared	-0.835360	S.D. dependent var	175.6195
S.E. of regression	237.9213	Akaike info criterion	13.93702
Sum squared resid	169819.6	Schwarz criterion	14.22640
Log likelihood	-68.65361	Hannan-Quinn criter.	13.75461
F-statistic	0.349789	Durbin-Watson stat	2.834898
Prob(F-statistic)	0.885962		

In both equations, the same seven independent variables are included as factors which determine agricultural enterprise technology innovation capacity for Monsanto and DBN Technology Group Co Ltd. From the regression results, β0=21.056 for equation 1 and β0=-37.43 for equation 2. The estimated coefficient of the constant term neither has aproiri expectation of zero nor negative. Thus the intercept of equation 2 violates the economic and statistical conditions. Also in both equations, the estimated coefficient values of RDEX, NNPM, NOP, SRG, RDP, NI AND GPS are not the same. This explains that these agricultural enterprises differ in their technology innovation capacities. R^2 is the total explainability of the models that is the overall fit of the independent variables for the dependent variable AETIC. The coefficient of determination R^2 is the fraction of the variance of the dependent variable explained by the independent variables. This explainability for equation 1, is approximately, R^2 = 60 percent, higher than equation 2 where R^2=45percent. The later is a weak explanation. The results have econometric problems of serial correlation and multicolinearity. This is because of the effects of possible omission of important variables (factors) that likely affect the AETIC. Also, the importance of included variables differs in relevance to the two enterprises. We found that some variables included in the estimated model were perfectly collinear, having some form of correlation. This made us repeated the estimation.

4. Findings

As an economic entity, we assumed that the primary motivation for agricultural enterprise innovation is its profitability. However, responses got from the questionnaire administered proved other primary motivation than profits, such as national food security, enterprise status symbol and peasants' benefits. Other factors such as government behavior (political and cultural environment), competition, market demand, innovation thinking, and size of enterprise, though interrelated, are secondary determinants. Agricultural enterprise innovation capacity has social, economic and ecological consequences. It impacts on land yield, resource efficiency, labor productivity, income, cost of inputs and environment.

The factors that influence the agricultural enterprise technology innovation capacity include its investment in R&D, market competition, customer satisfaction, resource availability, management capacity, company partnership, scientific and technical environment, government policy and the quality of R&D personnel. The outputs are new products and services, higher income, higher yields, employment, improved core competence, commercial linkages, profits and sustainable growth. Agriculture in DBN Group Co Ltd is a business. It is being resourced, researched, developed, financed and innovated as a business. DBN Group Co Ltd has strong R&D capability. It is a leader in China's feed and seed business with strong capacity in buying, developing and commercializing agricultural innovations (licensing and sublicensing innovations), obtaining and also paying royalties for new biotechnologies. Its innovation capacity constitutes a vital resource for domestic agribusiness. Agricultural enterprises with high innovation capacity tend to achieve faster and bigger success in industrialization and commercialization. Innovation capacity increases their market share and profit margin. Their competitiveness is rated high and they tend to bring more benefits to the shareholders and the consumers of their innovation. DBN, through partnership and external cooperation, has the capacity to develop new rice, corn and soybean varieties with improved drought tolerance and yield protection technology (YPT), heat and drought tolerance technology (HDT), water efficiency technology (WET) and yield enhancement technology(YET). This collaboration has provided opportunity for exchanges of yield enhancement and weatherproofing plant traits. There is possibility to stack these traits through advanced breeding and selection processes for development of a new generation of seeds with superior agronomic performances. The benefit of these alliances to the peasants is that the Chinese enterprises can form a fast track to deliver a new generation of high performance seed and feed products to the farmers.

4.1. Evaluation of results on the enterprise innovation capacity

The output of AETIC therefore, becomes the input to the farmer, a means to an end. The end products are increased agricultural productivity, increased incomes and national food security with environmental sustainability. A total number of 10 agricultural high-tech enterprises in China were visited with questionnaires. They include: DBN Group Co Ltd (DBN), China Seed Group Co Ltd (CGS), Beijing Origin Agritech Ltd (BOA), Beijing Lonke Fangzhuo Biological Engineering Technology Co Ltd (BLFBET), Beijing Jingyan Science and Technology Development Center (BJSTDC), China agro-Biotechnology Co Ltd (CABCO), Beijing GuangYuan Wanghe Seeds Co Ltd (BGYWS), Kaituo DNA Biotech Co. Ltd (K-DNA-B), Beijing Doneed Seeds Co. Ltd (BDS-LTD) and Monsanto. Employers with thorough knowledge of the enterprises and their strategic vision were contacted to fill the questionnaires. Enterprise confidentiality rules related to the release of any data were applied. Not all the questions were responded to, and not all responses were valid. The dimension of influence factors on innovation capacity, tested on the 10 sampled companies, using the unit-root test for non-stationarity is ranked in Table 1. Table 1 reports the unit root tests for each of the 10 enterprises in logarithm and in first difference. ADF is the augmented Dickey-Fuller test, PP is Phillips and Peron (1988) test.. They correspond to the root test with trend. Optimal Lag length is obtained from Akaike information criterion (AIC) embedded in the TSP COINT command. Values in brackets are the corresponding p-values. The results indicate that the variables are non-stationary in logarithm. Monsanto is ranked number 1 (in terms of enterprises resources, R&D investments, competition, external cooperation and innovation output). While DBN is ranked number2, Kaituo DNA Biotech Co. Ltd is ranked number 10. We chose only the first (Monsanto) and the second (DBN) to run the regression presented earlier.

Among the obstacles to innovation, uncertainty of outcome, risk and intellectual property rights violation are the most important barriers. The uncertainty of outcome explains that the market may be unknown, or too small or monopolized by established competitors. Also, it is not all R&D investments that result in successful innovation of new product, service or process. Intellectual property rights violations reduces the benefits accruing to the enterprise from their innovation output such as patents, licenses and trademark, thus making the business of innovation less profitable to the inventor. Patent policy ensures inventor's interest through the exclusive property right legislation. This guarantees the inventor's economic return from his invention to inspire the inventor. Policy inconsistencies make the business environment unfavorable for political and cultural reasons. Lack of capital is also a barrier to the enterprise technology innovation capacity, scoring 30% very high as seen the table 2 of responses below. These enterprises studied have very high (60%) annual expenditure on R&D as indicated in the table below. They have different capacities to encourage innovation. They all have sound financial status, as capital is not a major barrier to their innovation activities. However, the technical personnel support of top management and corporate culture are not the same. The managerial capacity to coordinate internal communication are also different but vital. Their motivations are rated different from the sampling results. The rate of response to market changes and communication with farmers are more rapid in some enterprises than the others. Though the R&D annual expenditures are high in all the enterprises, the R&D results (outputs) are not the same. Emphasis on staff training and the quality of R&D personnel are limited in most findings.

Table 1. Results of Tests for Non-Stationarity in the Logarithms of the 10 enterprises (Unit Root Test)

Variable (in log)	***Optimal Lag length***	***Rank***	***ADF***	***pp***
DBN	3	2	5.615(0.886)	18.642(0.652)
CSG	3	4	5.275(0.447)	14.08(0.483)
BOA	3	6	3.948(0.534)	9.681(0.439)
BLFBET	3	8	1.865(0.351)	3.823(1.352)
BJSTDC	2	3	5.109(0.0001)	15.669(0.541)
CAB CO LTD	2	7	3.254(1.00)	8.491(0.366)
BGYWS LTD	3	5	4.718(0.687)	10.652(0.458)
K-DNA-B	1	10	-2.058(0.444)	-9.521(0.206)
BDS-LTD	2	9	0.382(0.483)	-6.537(0.238)
MONSANTO	3	1	8.228(0.001)	48.663(0.854)

The pressure of competition would bring out enthusiasm and creativity of the enterprise, and stimulate the motivation and activity of enterprise innovation. Enterprises would try their best to improve operating mechanism and promote competence. Market competition is therefore an important motivating factor of enterprise innovation capacity. Also, the government's attitude, legal system and policy towards scientific and technical activity and innovation would directly affect the success of enterprise innovation. Government motivates enterprise and industry innovation through pushing, pulling, participating and supporting. In order to encourage enterprise innovation, government may use tax reduction, loans at low or discounted interest, and technological innovation risk funds to benefit enterprises. In order to force enterprises to carry on innovation and to eliminate backward products, technology, equipments or even management methods, government may use penalty price support, publish products elimination catalogue periodically, set punitive taxation (high tax rate and high interest rates). To start up technological innovation, government could sign government purchase contracts and apply assigned government plans.

Table 2. Barriers to innovation capacity

Obstacles	***Very high-***	***Higher***	***High***	***low***	***Very low***	***Average***
Uncertainty	-	10%	20%	30%	40%	1.4
IPR violation	10%	20%	10%	40%	20%	2.6
Market barrier	-	40%	20%	30%	10%	2.9
Lack of skilled staff	10%	20%	50%	20%	-	3.2
Policy inconsistencies	5%	5%	30%	20%	40%	2.15
High Cost	30%	20%	20%	20%	10%	3.4

Table 3. Factors influencing AETIC

Factor/rating	***Very high- (5)***	***Higher (4)***	***High (3)***	***Low (2)***	***Very low (1)***	***Average***
R&D	60%	20%	20%	-	-	4.2
Capital	40%	30%	20%	10%	-	3.9
Status	20%	20%	30%	10%	20%	3.1
Customer	10%	20%	40%	20%	10%	3
Competition	60%	30	10%	-	-	4.5
Government	40%	20%	20%	10%	10%	3.7
Profits	10%	20%	10%	40%	20%	2.6
Science &Technology	50%	30%	10%	10%	-	4.2
Personnel	60%	30%	10%	-	-	4.5
external partnership	50%	20%	20%	10%	-	4.1

Considering the peculiarity of Agricultural High-tech enterprises and their innovation capacity, we elaborate the scale of these enterprises from five aspects: ownership structure, staff numbers, R&D expenditures, annual sales income, and innovation outputs. The enterprises belong mainly to the seeds, feeds and livestock industries. The results from the data obtained are presented in the table below:

Table 4. Ranking the influence factors and benefits

Reasons/Ratings	5	4	3	2	1	Eva*
R&D Activities	53.1%	20.5%	10.2%	10.1%	6.1%	4.044
Human Resource Quality	52.3%	15.6%	12.8%	10.3%	9%	3.919
Management	30.5%	20.3%	10.2%	20.6%	18.4%	3.329
Market	40.4%	15.5%	20.4%	15.5%	8.2%	3.644
Government Policy	45.2%	30.1%	12.4%	8.2%	4.1%	4.041
Industry partnership and external cooperation	20.6%	30.4%	25.6%	12.8%	10.6%	3.376
Competition	15.3%	26.1%	30.2%	21.3%	7.1%	3.212
Capital	21.5%	20.3%	10.9%	13.8%	33.5%	2.825
Customers	30.4%	40.3%	12.1%	10.2%	7%	3.769
Employment benefits to the peasant farmers	40.3%	20.5%	10.3%	18.5%	10.4%	3.618
Farm costs reduction benefits to peasant farmers	30.5%	12.2%	20.1%	22%	15.2%	3.208
Increased income	20.2%	18.8%	12.6%	10.3%	38.1%	2.727

5= most important factor. 1= remote factor *Source: Field survey 2012*

** Eva=Evaluation.*

The main branches of business in the enterprises are seed industry, feed industry, chemical fertilizers industry, forestry and herds, plant and animal protection. Dabeinong Technology Group Co. Ltd main businesses are seeds, feeds, animal, and plant protection. We elaborated the scale of innovation capacity of the sampled enterprises based on several factors including; R&D expenditures, number of patents, staff, annual sales, Net income, total assets, operating income and total profits. Annual percentage increases in Dabeinong's total oprerating income and total profits are 47.3%, 69.4% and 65.2%, while other enterprises like the Grand Agriseeds had annual percentage increases of 7.5%, 8.2% and -2.37% during the same accounting period, (2009-2011). These show that the innovation capacity of the enterprises are not the same, and do not yield the same results.

Table 5: Comparison of selected companies' account for the period

ENTERPRISE	***TOI* (million Yuan)***			***Total Profits (million Yuan)***		
	2009	2010	2011	2009	2010	2011
Wanxiang Doneed Co Ltd	665,333,771	587,295,980	562,946,637	67,594,369	62,933,555	87,509,132
Grand Agriseeds Tech. Inc.	284,582,168	395,032,046	427,603,100	46,486,624	64,787,604	63,550,218
Winall Hi-Tech Seed Co. Ltd.	163,623,622	180,305,245	279,089,342	34,896,499	35,510,274	29,061,598
Yuan Longping Hi-Tech Co Ltd.	1,054,749,535	1,280,396,579	1,552,269,239	83,165,400	140,595,654	228,633,806
Hefeifengle Seed Co Ltd	1,046,325,211	1,504,448,162	1,619,745,078	77,661,193	109,070,577	59,905,465
Gansu Dunhuang Seed Co. Ltd	1,512,696,635	172,268,555	180,598,185	138,519,247	1,210,656,242	632,031,898
Shandong Dendhai Seeds Co. Ltd	579,117,295	937,803,817	1,152,988,833	185,383,212	388,145,805	478,088,373
Beijing Dabeinong Tech. Group Co. Ltd	3,975,377,635	5,248,384,826	7,835,999,796	333,832,160	377,203,823	623,140,027

** TOI=Total Operating Income* *Sources: Companies' annual report*

As indicated in the table above, there are changes in the companies' R&D expenditures, marked difference in R&D personnel, sales revenue, number of patents and net income. These are changes induced by Scientific and technological progress. Monsanto is by all standards larger, global and more aggressive in agribusiness than DBN Technology Group Co Ltd. Its innovation output is higher, and R&D Expenditure as percentage of annual revenue is higher than DBN. They have widespread impacts on the enterprise innovation capacity and also on the peasant farmers who use the innovation.

Table 6. Innovation survey

Year/Factor	***2007***		***2008***		***2009***		***2010***		***2011***	
Company	DBN*	MST**	DBN	MST	DBN	MST	DBN	MST	DBN	MST
R&D expenditure ($millions)	27.76	800	31.2	980	32.316	1,098	46.65	1,205	67.47	1400
No of new products to the market	2	5	3	5	4	5	4	7	4	6
No. of patents	2	5	4	8	4	8	5	9	14	11
Sales, Revenue Generation($m)	1,641	8,349	305	11365	168.5	11,724	1966	10,502	2707	10800
Research and development personnel	312	3000	463	3200	596	3500	779	4000	1268	5000
Net Income ($m)	800	2,000	820	2,024	700	2,109	815	1,109	830	2,500

** DBN=Dabeinong Tech. Group Co. Ltd, ** MST=Monsanto Company* *Sources: Annual Reports*

All expenditures and income are estimated in million US Dollars.

5. Discussion of findings on peasant farmers' benefits

About 50 questionnaires were administered to the peasant farmers. From the peasants' responses, DBN improved seeds and feeds helped in the conservation and rejuvenation of agricultural soils to support plant and animal lives. In most of the responses from Fujian and –Shanxi provinces, the quantity and quality of seeds, feeds and chemicals from the agricultural enterprises have directly impacted the quality and quantity of grains, meat, milk, eggs and vegetables being produced. The input capacity of DBN is stronger than its output capacity which is still on the average. The internal management and administrative innovation capacity is strong. Overall, DBN technology innovation capacity has been playing a prominent role in rural economic growth, food security, and poverty reduction in China.

DBN Technology Group Co Ltd has developed new technology in agrochemicals, quality feeds, hybrid seeds that are environmentally friendly, products that lower production costs and improve productivity, income and working conditions of the farmers. Some of the products include beibeiru, S5011, S812, S1211, 813, 1711, ruzhubao 5011(pig feeds). Others are Landingkang (pig desease control medicine), Judan 22 and nonghua 101 (hybrid corn seeds).

DBN Technology Group agricultural research and extension has made advances and improved patents on the very basic food products for daily nutrition such as corn, soybeans, rice, wheat, even vegetables, fruits and cotton. New strains of disease resistant poultry that is genetically modified, gene-altered pigs and cattle, etc have brought huge benefits to the farmers in various forms; food security and higher income generated from increased productivity. The enterprise is heavily investing in innovation that results in high economic benefits and improves the people's livelihood. DBN has used various methods for maintaining and increasing its competitiveness over the years such as patents, incentives, R&D investments, registration of design and having a lead time advantage over other competitors. Another strategy is the spread of its innovation through the market and non-market channels to the advantage of the peasant farmers. The national diffusion of DBN innovation has put the interest of domestic peasants ahead of any other motivation. The AETIC has influenced factors of production; manpower use, job creation, land use, material consumption, poor population and energy consumption amongst the peasants. The benefit to the enterprise is that these innovations have increased the enterprise's market share both at home and abroad.

In China, the rural income distribution began to change following the household responsibility system (HRS), otherwise known as the individualization of agricultural production in the 1980s. China has about 22% of the world's population with only 9% of the world's cultivated land (Jingyuan, 2011). This fact alone is a clear indication that advanced innovation in agricultural science and technology is needed in China.

The key to increasing incomes in the rural areas is to increase the productivity of farms through institutional reforms (example land reforms), R&D and agricultural technology innovation. From the period of HRS in the 80s, the resources devoted to science and technology in China have expanded rapidly till date. China now ranks amongst the top countries in total R&D spending and the number of researchers, (OECD, 2011a). However, R&D intensity remains low compared to OECD countries (1.5% of GDP as opposed to an OECD average of 2.2%). This is especially so in high technology industries (OECD, 2004). The R&D activity of the high-tech sector in China is only equivalent to that of the low-tech sector in advanced countries, (OECD, 2011b).

In a related study by Xiao and Zhu (2010), the benefit expectation factor is taken as the primary factor of technological innovation motivation. The model included and classified some factors, such as enterprise resource, competitors and entrepreneur's innovation thinking as secondary factors. An enterprise needs these key factors to strengthen its technological innovation capacity, and faces risk in the innovation, such as the uncertainty of success of technological innovation and the uncertainty of expected profit to be gained after success. The technological innovation capacity for an enterprise is a sum of the motivation factors, which exist inside and outside the enterprise's technological innovation system and have inner driving power on the activities of innovation. The agricultural enterprise may gain economic advantages and relative competitive superiority while it strengthens its innovation capacity. Pursuing profit maximization may be the primary target, but strengthening the innovation capacity becomes the means to an end.

Table 7. Benefits to peasant farmers

Germplasm crop seeds	***Very High (5)***	***Higher (4)***	***High (3)***	***Low (2)***	***Very Low (1)***	***Average***
Corn hybrids	20%	40%	30%	10%	-	3.8
Soybean varieties	-	50%	30%	10%	10%	3.2
Rice hybrids	20%	40%	20%	10%	10%	3.5
Cotton Varieties	20%	30%	10%	20%	20%	3.1

DBN seeds, feeds and chemicals provide farmers with solutions that improve crops and livestock's productivity, making peasant agricultural business cost-effective and profitable. The quality of corn hybrids such as Judan 22 and nonghua 101 is rated 40% higher, 20% very high and 30% as seen in table 2 above. The cotton hybrids recorded the very low benefits at 20% rating.

Among the objectives listed by the 10 agricultural high-tech companies include: innovation and sustainable development, employment, to attract talent for R&D, food security and to increase farmers' income. Six of the companies were private ownership, including DBN Group co. ltd, while the remaining four belongs to the government. The size of employees ranges from 24 to 10567. DBN Group has the highest number of employees with average monthly income of employees at 5000 Yuan. The incentive system of innovation in DBN Group is higher than most of the companies compared. It has a bi-annual science and technology award for excellent innovation achievements. The output of innovation is also highest in terms of new products, new market development, status symbol, trademark and new services. Its external innovation cooperation is also rapidly increasing. Within China, the company is empowering farmers with science and technology, higher crop genetic breeding, crop biotechnology and a more comprehensive famers' training. The relationship with the peasant farmers is strong in these regards. The company is helping peasant farmers to commercialize agriculture at the rural level, innovating agriculture and providing agricultural extension services/incentives, skill training and knowledge acquisition. All the 10 agricultural high-tech companies confirmed in the questionnaire that their companies have external science and technology innovation cooperation with other companies, research institutes, or universities to conduct research and development (R&D), and that these cooperation have strengthened their innovation capacity. There is need to pay more attention to peasant farmers. Information and Communication Technologies (ICT) can be utilized to empower farmers, disadvantaged minorities in the rural and isolated regions.

Table 8. Benefits: culture vegetable seeds

Benefits/ Rating	***Very High (5)***	***Higher (4)***	***High (3)***	***Low (2)***	***Very Low (1)***	***Average***
Carrot	-	10%	30%	25%	20%	2
Tomato	-	15%	40%	5%	-	1.9
Cucumber	-	15%	40%	5%	-	1.9
Melon	-	10%	35%	15%	-	1.75
Pumpkin	-	10%	25%	25%	-	1.65
Pepper	-	10%	40%	5%	-	1.75
Egg Plant	-	15%	25%	15%	-	1.65
Beans	-	10%	40%	5%	-	1.53
Squash	-	10%	25%	20%	-	1.65
Onions	-	10%	25%	20%	-	1.65
Lettuce	-	10%	30%	20%	-	1.43
Broccoli	-	10%	25%	15%	-	1.45

About 50 Questionnaires were administered and 50% of the respondents say DBN Group science and technology demonstration bases were rated high, 40% say that DBN expert workshops have high benefits for peasant farmers, while 60% confirmed that they have high benefits from the company's media information dissemination. DBN Group also scores 45% high for its technology transfer role for peasant farmers and the science and technology awards. Famers' changing demands and their feedback are the invaluable sources of technological innovation for the agricultural enterprise. Successful innovation capacity means accurately understanding the changing demands and fitting new products or service into market demands.

DBN Group occupies an advanced position in the China agricultural technology innovation capacity and market competition.

Table 9. DBN innovation benefits for peasants

Benefits/rating	Very High (5)	Higher (4)	High (3)	Low (2)	Very Low (1)	Average
Local Govt. Partnership	-	20%	25%	30%	-	2.15
S&T demonstration bases	-	30%	50%	-	-	2.7
Expert Workshop	5%	30%	40%	-	-	2.65
Media Information	10%	15%	60%	15%	-	3.2
Technology transfer	5%	15%	45%	10%	-	2.4
S&T Awards	5%	10%	45%	10%	-	2.2

Table 10. Benefits to peasant farmers (2)

Benefits/rating	Very High (5)	Higher (4)	High (3)	Low (2)	Very Low (1)	Average
Cost advantage	-	-	20%	30%	50%	1.7
High yield	20%	20%	25%	15%	-	2.85
Income	-	10%	45%	25%	-	2.25
Technology transfer	-	10%	50%	5%	-	2
Environment	-	10%	40%	20%	-	2
Employment	-	-	35%	45%	-	1.95

Majority of the peasant farmers say they have benefited the least from reduction in the cost of adoption of agricultural enterprise technology innovation. 50% of the respondents say the cost benefit from these innovations is very low. They rather lay claims to the high cost of adoption as a major barrier to peasant farmers' adoption of innovation. This is shown in the table below:

Table 11. Factors affecting AETIC adoption by peasant farmers

Factors/Rating	***Very High (5)***	***Higher (4)***	***High (3)***	***Low (2)***	***Very Low (1)***	***Average***
Awareness	-	20%	30%	50%	10%	2.8
Costs	30%	50%	20%	-	-	3.1
Expected benefits	10%	15%	20%	30%	-	2.3
Natural factors	20%	40%	20%	10%	-	3.4
Soil quality	10%	30%	30%	5%	10%	2.8
Farm size	-	10%	10%	30%	40%	1.7

Economic incentives are important to the adoption of agricultural innovation; input and output price policy, subsidy, free extension and farmers' education, agricultural credits increase the incentive to adopt new technologies.

Table 12. Output of AETIC

Output/rating	***Very High (5)***	***Higher (4)***	***High (3)***	***Low (2)***	***Very Low (1)***	***Average***
New products	20%	40%	30%	10%	-	3.7
New services	30%	20%	25%	20%	5%	3.5
New process	10%	25%	30%	10%	15%	2.75
Management	20%	20%	40%	10%	10%	3.3
Trademark	10%	30%	20%	15%	5%	2.65
Patents	15%	25%	30%	5%	10%	2.85

Management ability to deal with administration of human and material resources, the business culture, enterprise evolution and industry revolution, management quality and internal communication also impact on innovation capacity.

The development and diffusion of enterprise innovation are central to the growth of agricultural output and productivity. Its outcome has economic impact on both the enterprise and the end-users (farmers). DBN Technology Group innovation has expanded its innovation capacity as the quality of seeds, feeds and chemicals have yielded to improved quality of meats, fruits, vegetables and grains. It has caused significant changes in the structure of domestic foods, marketing and agriculture. The availability of sources of funding to finance innovation, such as venture capital, stock markets, mortgage markets, credit lines have enabled the enterprise to advance R&D investment and innovation diffusion. It has changed the quality and quantity of grains produced and brought multiple benefits to the farmers. While the enterprise is the producer and generator of innovation, the farmers are the consumers of the innovation. Innovation is improving local capacity-building, generating change in traditional farming and enhancing rural residents' wellbeing. Peasant farmers are adopting new significantly improved methods and farming practices. The social gain from innovation research may be high, but the rate of returns to the enterprise is still low, due to difficulty in marketing the innovation. This tend to make the cost of innovation investment higher than the benefits to enterprise, hence some form of policy compensation is needed Patent protection is the most obvious policy incentive to innovation activities which enable innovators to reap the benefits from their investments. Having science and technology cooperation with more than 100 local governments, established more than 200 agricultural science and technology demonstration bases and agricultural expert workshops, DBN Group innovation capacity is rated high in China. The enterprise offers latest agricultural technology information to the farmers. Media information dissemination (TV, radio, telephone, newspapers and magazines) are part of the innovation capacity building process. Building websites for agricultural technology and extension, unification of agricultural science and technology with practical farming in the provinces are enhanced. Innovators of new patentable technology have the property right for its utilization. Other incentives include handsome rewards (prizes) for the inventor (Wright, 1983). DBN Technology Group uses prizes in its biannual Science and Technology Awards (DBN STA) to induce creative solutions to agricultural technology problems. Other main sources of institutional inducement (official and social incentives) also come from the government. The benefits of AETIC stem not only from the creation of knowledge, but extend to its diffusion and application for economic impact. The diffusion of AETIC is the spread to different markets and farmers. Without diffusion, innovation is not complete. The interaction between market opportunities and the enterprise's knowledge base and capabilities can be of huge economic significance. These create jobs and more income for the peasants in the long-term.

6. Recommendation

The agricultural enterprises in China need to bring access to technology to more farmers. There is need for increased investment in agricultural research and development. Based on the survey, human resources, R&D investments, technology transfer, cost of adoption, productivity, employment, food security and sales revenue are related to the enterprise innovation capacity. DBN has a rapidly growing agricultural technology capacity. However, the sum of the assessment shows that innovation capacity is still limited among the investigated enterprises. Most of the patents are for the adaptation of technology rather than new inventions.

This is not unconnected with insufficient R&D experts. Inadequate qualified staff to handle R&D is a minus on the innovation capacity. This reinforces the recommendation that, with staff training, education, more R&D investment, the innovation capacity and its benefits will be stepped higher. Government policy support for agricultural technology will facilitate further commercialization and competition in the industry. Government support and policy stability will further create an enabling environment for profitable private enterprises innovation activities and agricultural development. Extension, education and training should be organized to sensitize peasant farmers on the potential benefits from adopting innovation. This will meet the present-day challenges and for the future. Chinese agricultural private enterprises should take advantage of the various government policy supports to strengthen their innovation capacity and reposition themselves for global agribusiness. The Haidian Park related agricultural industries should take this lead as they are at the center of innovation in China. The government should introduce favorable tax reductions in order to encourage private agricultural enterprises to focus more on scientific innovation and bring new research achievements to the market. Also, government should increase financial support for agricultural research while attracting loans and venture capital to enterprises that generate agricultural technology. Agricultural enterprises should build more research laboratory, and channel their innovation capacity into R&D projects that are related to agricultural development and farmers' benefits. The local authorities should further promote agricultural technologies in their provinces, counties, districts and villages. The agricultural enterprise should offer more farming guidance to grassroots farmers. AETIC cooperation enhances international learning and exchange of knowledge and skills on agricultural science and technology, and fosters a strategic partnership for commercialization and industrialization, with complementary advantages. The productivity and profitability of small farmers should be the key policy target for enterprise technology innovation capacity. Government policy to encourage private R&D through such measures that create new market in rural areas, tax incentives and strengthening intellectual property rights, and support input-related industries in seeds, feeds, fertilizers, chemicals, irrigation and communication infrastructures and electricity are recommended. The enterprise can learn from the peasant farmers through participatory approaches, technology transfer, and diffusion for benefits innovation. Peasant farmers are the main producers and innovators. Their experiences have to be shared with the enterprise to improve the latter's innovation capacity and maximize the benefits for both. The enterprise need to:

- Encourage farmer groups
- Develop peasant partnerships for action

Enterprises should strengthen their grassroots' contacts and develop stronger partnerships. They should teach and empower farmers to innovatively manage soils. With these, peasant's experiences in using the enterprise innovation can be shared within the local communities, and also with the enterprise. Enterprise investments in, and experiments with new agro ecological practices which will provide higher yield and conserve the productive capacity of the rural ecosystems need the constant support from the government. The costs of transition from the traditional to modern agriculture are too high beyond the peasant in poor areas. They need the support of the enterprise and the government in acquisition of hybrid seeds, introduction of integrated pest management, integrated plant and animal nutrition management, as well as soil and water conservation. If the costs of adoption are not reduced, poor peasant farmers will continue to reap the least benefits from enterprise innovation. We also recommend public-private partnerships for improved commercialization of applied knowledge and technologies. There should be adequate incentives and rewards to encourage private investments in ATIC contributing to sustainable development. It is necessary to complement these investments with increased and more targeted investments in rural infrastructure, education and health.

7. Conclusion

This study aimed to evaluate the factors that influence the AETIC, as they work to improve peasant farmers' access to, and benefits from such innovation. The technology innovation capacity is not uniform among the 10 companies investigated. The innovation capacity is influenced by the size of the enterprise, R&D investment, market competition, R&D personnel, net sales, returns on investment (ROI), and external technology cooperation, among others. AETIC is needed to reduce production costs in order to make food affordable to the consumer and profitable for the farmer. Growing population, land shortages, high input and food prices, rural poverty, destruction of the ecosystem, and variable climate are the major reasons working for improved AETIC. China needs to produce more food. It is not safe for China to base its citizens' access to food on net imports. This is because the speculative global market is volatile. There is increasing export restrictions from food exporting countries. This calls for the support for small-scale farmer through policy and investment. Encouraging peasant adoption of innovation is the key. Peasant farmers have shown that they can produce more food under an enabling environment created by the government and enterprise innovation support. They need access to low and stable prices of innovation in order to increase production. The peasant market access requires rural infrastructure, storage facilities, rural roads and electricity.

AETIC impacts on land yield, resource efficiency, labor productivity, income, cost of inputs, employment and environment. The leading example of Monsanto compared with others shows that enterprises with high innovation capacity tend to achieve faster and bigger success in industrialization and commercialization. DBN technology includes high yield varieties of corn, rice, soybean, cotton, vegetable, feeds additive, pesticides, insecticides and herbicides. DBN has sufficient innovation capacity, has adequate information on technology and several opportunities for international technology cooperation with world leading agricultural high technology enterprises. However, in the 10 enterprises, there are issues to be seriously considered. Firstly, there are not enough new technological and innovative results. Secondly, technology is not promoted enough in rural areas. Thirdly, the external cooperation is not enough to qualify for China's "Going Global Strategy". And finally, there is a great lack of technological personnel in the R&D departments.. The higher the innovation capacity, the more the enterprise enjoys economies of scale, reduced costs, increased affordability by the peasant farmers, higher sales revenue and benefits innovation. The farmers who adopt each kind of innovation increase crop productivity which leads to overall economic and social development of the farmer. Crop yield does not depend on the total area (hectare) sown in a year, but on the amount of improved inputs; high yield variety (HYV) seeds, insecticides, pesticides, herbicides, irrigation, fertilizers and farming techniques. Commercialization may require more research and market innovation that will result in new foreign markets, extra patents and more social and commercial benefits. The benefits to the peasant farmers in poor areas include reduction in farm costs; the supply of agro-chemicals and biotechnology techniques, expanded input and output markets, feeds supplies, improved seeds, diversified peasant livelihood, reduction in poor population, food security, improved rural income, and improvement in the rural socio-economic lives.

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