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## Exploring the Environmental Kuznets Curve Hypothesis between Economic Growth and Farmland Conversion in China

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The environmental Kuznets curve shows that environmental quality actually improved as incomes and levels of consumption went up. One might expect to observe EKC pattern between economic growth and farmland conversion. The country and province level data during 1987 to 2005 from China confirmed that such inverted U-shaped relationships between economic growth and farmland conversion are not a theoretical curiosity. The results show the scale of farmland conversion will go up with economic growth at beginning, after reaching to its peak value, then turn to go down with further economic growth. In addition, the peak value will be reached when per capita GDP gets to 16,002.42 RMB (in fixed 1986 prices). However, the peak values appear to vary with region and time.

**Keywords:** Environmental Kuznets Curve (EKC); Farmland Conversion; Economic Growth.

### INTRODUCTION

Since 1991, when economists first reported a systematic relationship between income changes and environmental quality, the relationship known as the Environmental Kuznets Curve (EKC) has become standard fare in technical conversations about environmental policy (Grossman and Krueger, 1991). EKC has its reference to Simon Kuznets because of his famous findings of an inverted U-shaped relation between income inequality and per capita GDP for different countries (Kuznets, 1955). The EKC hypothesis postulates that, as income grows, levels of pollution will initially rise, gradually reach the threshold point, and subsequently decline if economic growth proceeds far enough. This pattern is generally named as inverted-U-shaped relationship. If true this is a powerful and attractive policy implication, suggesting that the pursuit of economic growth and a cleaner environment in the same time frame need not work against one another (Deacon and Norman, 2004).

In the last few years, the EKC hypothesis has been analyzed systematically within many countries for various environmental indicators. Under this framework scientists usually take data of air pollution, water pollution or deforestation as the indicators of environmental quality. In developed countries farmland has long been recognized as a provider of environmental amenity in addition to its traditional role as a primary input of agricul-

tural production (Aliza Fleischer and Yacov Tsur, 2005), because farmland generates environmental purification, open space, aesthetic landscape, excursion destination, culture preservation and so on. As a parcel of farmland converted into developed area, the quality of environmental amenity in the neighborhood definitely turns into worse. In a larger scale, obviously farmland conversion plays an important role in Land use/Land cover change (LULCC), which is being recognized as the key driver of environmental change (Backstael, 1996), for land use change at one scale or another is perhaps the single greatest factor affecting ecological resources (Hunsaker and Levine, 1995). In some degree, farmland conversion actually represents the decrease of environmental quality. So does EKC hypothesis exist between economic growth and farmland conversion? The research is mainly intrigued by this question.

Now the amazing farmland conversion is undergoing in China. Between 1986 and 2005 the average annual GDP growth rate is 9.2%, while averagely 1,894 km<sup>2</sup> farmland was converted into non-agricultural industries annually. The total conversion area is equal to 3.1% of the amount of farmland in 2005. What will happen to the scale of conversion in the future? Could farmland conversion be compatible with economic growth? Is there any EKC-relationship between economic growth and farmland conversion in China? To answer these questions, firstly we analyze the impact of economic development on farmland conversion, the change of the demand for land resource in different stages; therefore examine the temporal trends of farmland conversion and per capita gross domestic product (GDP) in some provinces. Then we test EKC model (Stern, 2004), using per capita GDP as the income variable and area of farmland conversion as the scale variable. In the end, we discuss the empirical results and its policy implications.

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## ECONOMIC GROWTH AND FARMLAND CONVERSION

### Effects of Economic growth on farmland conversion

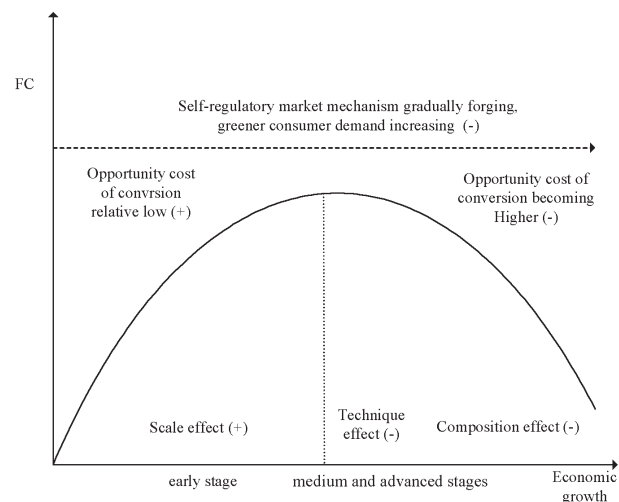
Obviously farmland conversion can satisfy the increment of demand induced by economic growth. It plays an important role in sustaining continued economic growth but it also has many negative effects. The interaction between economic growth and farmland conversion can be illustrated from following three aspects.

At one perspective, as Grossman (1995) first suggested, it is possible to distinguish three main channels whereby income growth affects the quality of the environment, which are so-called scale effect, composition effect and technique effect. In the case of farmland conversion, for differential marginal interest between farm and non-farm at the early stage of economic development, scale effect propels farmland conversion rapidly, so farmland conversion keeps step up with economic growth. In the second place when economy reaches a higher level, economic growth can have a negative impact on the farmland conversion by a composition effect. The structure of economy tends to transfer from land-intensive industry to less land-intensive industries, such as services and technology-intensive industry. As a result, farmland conversion progress begins to slow down. Finally, technological progress often occurs with economic growth when a wealthier economy can afford to spend more on research and development. Through adoption of new technology, substitute for natural resources by man-made resources, more effectively utilization of land resources, technology effect also counteract progress of farmland conversion. The scale effect tends to prevail in the initial stages of economic growth, but it will be outweighed by the composition and technique effects in inter-medium and advanced stages.

At another perspective, as World Bank (1992), Unruh and Moomaw (1998) presented, there is an endogenous self-regulatory market mechanism for those natural resources that are able to be traded in markets. This mechanism can prevent environmental degradation from continuing to grow with income. Take farmland as example; in early stage of economic growth farmland tends to be converted from agricultural sector to industrial sectors because of differential marginal profit. The stock of farmland decreases and the scale of farmland conversion increase over time in this stage; consequently with farmland scarcer and policy invention more strict, the opportunity cost of conversion increases significantly, the price certainly rises correspondingly. Of course, the progress of farmland conversion will go downward. Moreover, higher price also contribute to accelerate the shift toward less land-intensive and high utilizing-efficiency technologies.

In addition, Conversion can be considered as one form of natural resources depletion, as well as which threatens food security, destroys farmland's multifunction (including water and air purification, habitats, recreational services etc.), decreases the biodiversity of agroecosystem, worsens environmental amenity. So in

some degree it's not abrupt to argue that farmland conversion is worsening the environmental quality. Since environmental quality is truly of luxury nature, in relatively high-income economies the income elasticity of demand for commodities and services related to sustenance is low and declines as income continues to rise, while the income elasticity of demand for more effective disposal of residuals and for environmental amenities is high and continues to rise. This is in sharp contrast to the situation in poor countries where the income elasticity of demand is high for sustenance and low for environmental amenities (Ruttan, 1977). The following fact can be proofed based on this view. As income grows, people are eager to achieve a higher living standard and care more for the quality of the environmental quality. They gradually prefer field trip, recreational enjoyment, more rural area. According to the income elasticity of environmental demand, so they will increase their willingness to pay for the protection for farmland. The goal of policy invention in farmland conversion will upgrade from protecting production to maintaining environmental amenity, therefore government will also employ more policy instruments to control the process of farmland conversion.



**Fig. 1.** The analysis sketch of economic growth and farmland conversion.

Notes: FC denotes farmland conversion, the same as henceforth, (+) denotes positive effect on farmland conversion, (-) denotes negative effect on farmland conversion.

### The scatter graphs of Economic growth and farmland conversion in China

We choose respectively four provinces in coastal, middle, west areas of China as examples. Using the scatter graph to depict the development between economic growth and farmland conversion<sup>1</sup>, all the trends in fig. 2 clearly exhibit polynomial relationship (up to degree three). The fit curves perform inverted U shape or N shape. These intuitively get us to make the presentation and estimation of EKC hypothesis on farmland conversion.

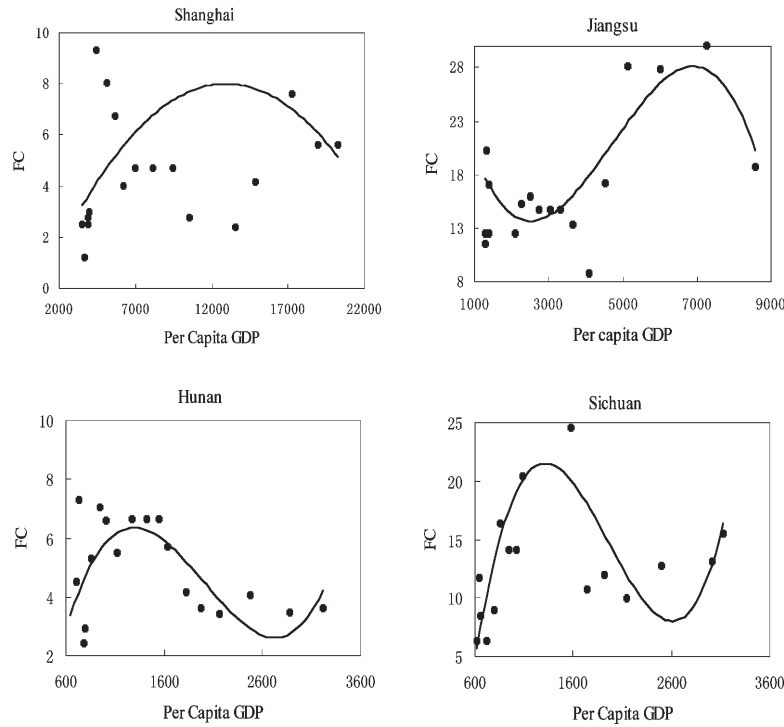


Fig. 2. Scatter graph of FC and economic growth in some provinces.

#### HYPOTHESIS AND ECONOMETRIC MODEL

We adopt theoretic method by using per capita GDP as explanatory variable to indicate the level of economic growth, area of farmland conversion as dependent variable to indicate the environmental quality decreasing. We apply both time-series and panel-data approaches to examine the existence of EKC relationship.

Because of the limitations to availability of farmland conversion information in China, we use the cultivated land conversion data from 1986 to 2005. Among them the data from 1987 to 1998 at country and province level was obtained from Chinese agriculture yearbooks issued by Ministry of Agriculture of People's Republic of China, others from Chinese land resources yearbooks issued by Ministry of Land and Resources of People's Republic of China<sup>2</sup>. Besides, all data related to per capita GDP and population was collected from Chinese statistical yearbooks from 1987 to 2006 issued by Chinese National Statistical Bureau. We use real GDP instead of nominal GDP<sup>3</sup>. In addition, because of administrative change in

China, we can only get 30 provinces' data related from 1986 to 2005<sup>4</sup>.

To be specific, country level model is illustrated by time series equation in natural logarithm form, and province level by fixed effects equation in level form<sup>5</sup>. The models are given as:

$$\ln(FC_t) = c_0 + c_1 \ln(PGDP_t) + c_2 (\ln(PGDP_t))^2 + u_t \quad (1)$$

$$FC_{it} = \alpha_i + \theta_t + c_1 PGDP_{it} + c_2 (PGDP_{it})^2 + u_{it} \quad (2)$$

Where subscript  $t$  refers to time 1986 to 2005,  $FC_t$  denotes the area of farmland conversion in China,  $PGDP_t$  denotes per capita GDP in China. Respectively,  $FC_{it}$  is the area of farmland conversion in province  $i$ ,  $PGDP_{it}$  is per capita GDP in province  $i$ .  $c_0$  is an intercept term while  $u_t$  and  $u_{it}$  are white noise error term.  $\alpha_i$  are cross-sectional effects,  $\theta_t$  are time effects.  $\ln$  indicates natural logarithm transformation. Eq.(1) and eq.(2) allow one to test five kinds of farmland conversion-economic relationships:

<sup>1</sup> For lack of data, in empirical analysis all the data of farmland conversion only includes the area of cultivated land that was converted into non-agricultural sectors, doesn't include pasture, timber land and others. Actually most of conversion in China takes place in cultivated land.

<sup>2</sup> Chinese National Land Administration Bureau, a former institution of Ministry of Land and Resources, was just founded in 1986. This resulted to the inconsistencies in data reporting. For the integrity of data, we respectively chose two resources.

<sup>3</sup> All per capita GDP data of observed year is adjusted. The current prices are converted to fixed prices in 1986 by using consumer price indices from Chinese Statistical yearbooks 1987–2006. Otherwise, without adjustment the analysis would be distorted by inflation. GDP is in 10,000 RMB.

<sup>4</sup> Our research only focus on the mainland of China, now in total there are 31 provincial units in the mainland. For the consistency of historical data, because Chongqing municipality was founded in 1997, and it used to belong Sichuan province, so we incorporate Chongqing into Sichuan in data.

<sup>5</sup> Theoretically, we can also use natural logarithm form to estimate panel data equation, but there are some zero values of FC in our data set, so we can't perform the transformation.

(i)  $c_1 > 0$  and  $c_2 = 0$  implies a monotonic increasing relationship indicating that higher economic level are associated with larger scale of farmland conversion;

(ii)  $c_1 < 0$  and  $c_2 = 0$  implies a monotonic decreasing relationship indicating that higher economic level are associated with smaller scale of farmland conversion;

(iii)  $c_1 > 0$  and  $c_2 < 0$  implies an inverted U-shaped quadratic relationship representing the EKC pattern and indicating that higher economic level are associated with declining scale of farmland conversion after a critical level has been reached;

(iv)  $c_1 < 0$  and  $c_2 > 0$  implies a U-shaped quadratic relationship, opposite to the EKC;

(v)  $c_1 = c_2 = 0$  implies a flat pattern indicating that the scale of farmland conversion is not affected by the level of economic development.

If the regression coefficient  $c_2$  in eq.(1) or eq.(2) is negative significantly as (iii), EKC pattern should exist between economic growth and farmland conversion. So the goal of econometric analysis is to examine the mathematical relationships in eq. 1) and eq.(2) as the above.

## EMPIRICAL ANALYSIS

### Time-series regression

Before estimation, we test the stationary of series  $\ln(PGDP)$ ,  $\ln(FC)$  by ADF and KPSS<sup>6</sup>. We find that they are both stationary. During estimation, the results are not significantly in statistics, and then we adjust the length of time series, reduce the data of 1987<sup>7</sup>. The series turn into 1988 to 2005. The final results are reported as follows in eq. (3):

$$\ln(FC) = -44.5946 + 13.4560 \ln(PGDP) - 0.9061 (\ln(PGDP))^2 \\ (-3.0481) (3.3933) \quad (-3.3816) \quad (3)$$

$$R^2 = 0.4380 \quad F = 5.8456 \quad \text{Prob}(F\text{-statistic}) = 0.0133$$

with T-values in brackets. The results of T-tests indicate that we can accept the null hypothesis that the intercept and coefficients in eq.(3) are significantly not zero at confidence level 0.05. The result of F-test shows that eq.(3) exists statistically strongly. In addition, we test autocorrelation by plus AR (1) term and check heteroskedasticity by white test. They both don't exist. There is the positive effect of per capita GDP, the negative effect of per capita GDP squared as priori expected. This is a phenomenon that EKC pattern will occur. Unfortunately, the R square of eq.(3) is just 0.438, it's too low that the estimation may distort the real situation, so we can't deduce that EKC relationship certainly exists between economic growth and farmland conversion. The analysis will continue in the following.

### Panel data regression

For spatial heterogeneity and unobservable variables, relationship between economic growth and farmland conversion may vary among provinces. The general formulation as displayed in eq.(2) includes also provincial specific effects  $\alpha_i$ , and time effects  $\theta_t$ . Furthermore, for simplifying the analytic process; we model provincial and time effects in eq.(2) as fixed effects. We assume that intercept term being correlated with the explanatory variables and let the intercept vary among provinces. Meanwhile, we adopt white cross-section method to eliminate the heterogeneity. The results are reported in table 1. Fixed effects model is captured in a single equation due to increased per capita GDP for all provinces over the time period from 1987 to 2005. The single equation of eq.(2) is as the following:

$$FC = 3.5907 + 0.0013 PGDP - (4.14E+08) PGDP^2 \quad (4) \\ (4.0100) (0.0028) \quad (0.0270) \\ R^2 = 0.7033 \quad F = 25.1515 \quad \text{Prob}(F\text{-statistic}) = 0.0000$$

**Table 1.** Panel data regression, fixed effects model

Variable	Coefficient	t-statistic	Prob.
Constant	3.5907	4.0100	0.0001
PGDP	0.0013	2.9987	0.0028
PGDP <sup>2</sup>	-4.14E-08	-2.2177	0.0270
Fixed effects (cross)		Fixed Effects (Period)	
Beijing-C	-6.7129	1987-C	2.1790
Tianjin-C	-8.0507	1988-C	0.3472
Hebei-C	2.8658	1989-C	-0.5990
Shanxi-C	-0.5470	1990-C	-1.0893
Neimenggu-C	0.4084	1991-C	-1.0091
Liaoning-C	-1.7091	1992-C	1.9434
Jilin-C	-3.0589	1993-C	3.4455
Heilongjiang-C	0.7058	1994-C	2.4529
Shanghai-C	-5.4219	1995-C	1.7266
Jiangsu-C	10.2866	1996-C	0.9885
Zhejiang-C	5.6057	1997-C	0.7576
Anhui-C	4.3728	1998-C	0.2416
Fujian-C	-3.1790	1999-C	0.0348
Jiangxi-C	-1.5381	2000-C	-1.6715
Shandong-C	14.3900	2001-C	-1.9413
Henan-C	4.3864	2002-C	-1.1891
Hubei-C	1.0066	2003-C	-0.5547
Hunan-C	-0.6501	2004-C	-3.8483
Guangdong-C	1.0114	2005-C	-2.2146
Guangxi-C	-0.6778		
Hainan-C	-4.4780		
Sichuan-C	9.3707		
Guizhou-C	-1.1109		
Yunnan-C	0.6448		
Xizang-C	-5.4588		
Shanxi-C	0.7084		
Gansu-C	-3.6259		
Qinghai-C	-4.8221		
Ningxia-C	-4.4068		
Xinjiang-C	-0.3153		
R-squared	0.7033	Adjusted R-squared	0.6753
F-statistic	25.1515	Prob (F-statistic)	0.0000

Notes: The confidence level is at 0.05. -C represents constant.

<sup>6</sup> The test results are reported in detail in appendix.

<sup>7</sup> In the end of 1986, China enacted and implemented the law of land administration to protect farmland and control farmland conversion. So this change deeply influences the progress of farmland conversion.



$(PGDP)^2$  imposes significant negative effect on farmland conversion, and  $PGDP$  imposes positive effects on farmland conversion. Comparing with the results of eq.(3), the significance level of coefficients and R square are improved greatly, so we can conclude more confidently that EKC relationship exists between economic growth and farmland conversion.

### Threshold value

According to EKC hypothesis, as per capita GDP reaches the threshold value, the scale of farmland conversion will get to its peak. So if we can get the threshold value, we can know more specifically about the progress of farmland conversion with economic growth.

For eq.(4), when farmland conversion achieve its maximum value, the corresponding  $PGDP^*$  reaches threshold value at the same time, the condition as the following,

$$\text{Supposing } \frac{\partial FC}{\partial PGDP} = c_1 + 2 * c_2 * PGDP^* = 0$$

$$\text{We can get } PGDP^* = -\frac{c_1}{2c_2}$$

So for eq.(4), the threshold value<sup>8</sup> is located at:

$$PGDP^* = -0.0013 / (2 \times (-4.14E-08)) = 16,002.42 \text{ RMB} \quad (5)$$

Comparing threshold value with the present level, we find that most of provinces are below threshold point. For example, per capita GDP in 2005 is 5,305.82 RMB, Shanghai, Tianjin and Beijing rank top 3, they are respectively 19,014.17RMB, 15,054.73RMB and 14,994.04RMB; other relative developed coastal provinces such as Zhejiang, Guangdong and Jiangsu, they are 9,496.93RMB, 8,723.53RMB, 8,600.83RMB. And the relative undeveloped provinces such as Guizhou, Yunnan and Gansu, only 1,767.76RMB, 2,647.67RMB and 2,652.3RMB. According to present economic condition, only Shanghai exceeds the threshold value, Tianjin and Beijing approach it, other provinces including Zhejiang, Guangdong and Jiangsu still have a long way to it. So for most of regions in China, the progress of farmland conversion is moving upward, the scale is increasing with the economic growth.

### Peak level of farmland conversion varies among regions and changes over time

Observing the characteristic of eq.(2) and eq.(4), all provinces exhibit the same EKC pattern. In particular, they all share the same threshold point  $PGDP^*$ , but the peak levels<sup>9</sup> of all farmland conversion differ across via provincial specific effects (see fixed effects (cross) in table. 1). The nature is showed as Fig. 3. Though threshold value of PGDP is equal among all provinces, the peak level of farmland conversion can differ among them.

If the intercept of EKC equation is larger, corre-

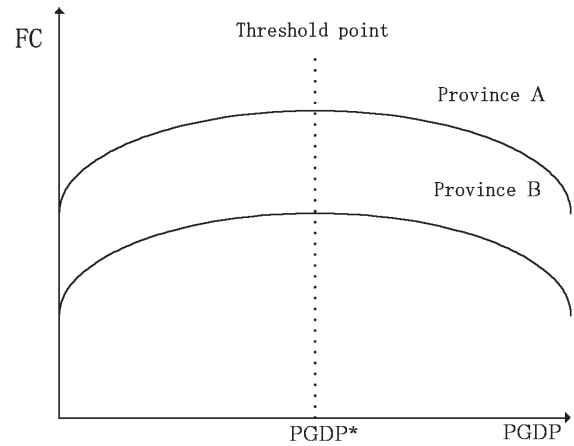


Fig. 3. An EKC for two provinces A and B.

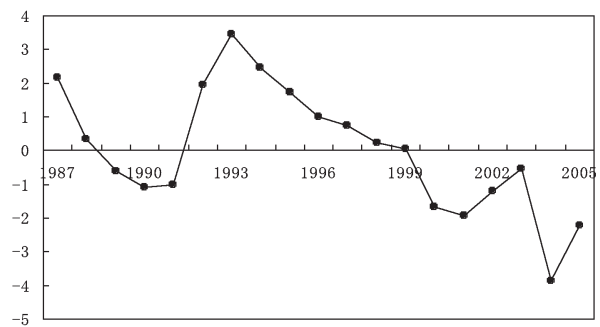


Fig. 4. The Change of Period Sepecific Coefficients (Fixed Effect).

spondingly the peak level is higher. The peak values of farmland conversion in different provinces have a positive relationship with the constants of cross fixed effects in EKC model. As the results of Table. 1, we know clear that expected peak values of farmland conversion in the following provinces Tianjin, Beijing, Shanghai, Shanghai, Xizang, Qinghai, Ningxia, Hainan, Gansu, Fujian, are rather low; in contrast, Shandong, Jiangsu, Sichuan, Zhejiang, Henan tend to be high; others locate intermediately.

The similar facts happen through time effects. The expected peak values of farmland conversion in different periods also have a positive relationship with the constants of time fixed effects in EKC model. We illustrate the change of expected peak value over time in Fig. 4. The intercept started to decrease over 1993, the expected peak value seemed going down over time.

### CONCLUSION AND DISCUSSIONS

Through econometric analysis, we find that EKC hypothesis between economic growth and farmland conversion in China is tenable. The scale of farmland conversion will initially increase in early stages, and the turning point is certain time when real per capita GDP in China reaches 16,002.42 RMB (in fixed 1986 prices),

<sup>8</sup> Per capita GDP is in fixed 1986 prices, the same as follows.

<sup>9</sup> Obviously peak values here are the expected value from eq.(4), which are inaccurate, just suit for relative comparison.

after that the scale of farmland conversion will decrease with economic growth continuing. Moreover, compared with present economic level in China, there is still a long way to reach the turning point. At the moment, only Shanghai already exceeded it, Tianjin and Beijing is approaching closely, but the rest regions are still far away from it. When real per capita GDP in China get to the present level of Shanghai, the scale of farmland conversion could reach its peak value. In addition, the intercepts of fixed effects model reveal that peak values of farmland conversion vary among different regions, also change over time.

Obviously, our conclusion lends evidence for the argument that farmland conversion can be compatible with economic growth if appropriate policy responses have been taken. Here some questions should be explored more explicitly. Firstly, as the conclusion though the scale of farmland conversion can perform EKC path with economic growth, the farmland would be consumed excessively in the future without active policy interventions. Secondly, according to the present situation in China, achieving the downturn of farmland conversion may be a long process that takes several decades. Therefore, if the government let farmland conversion evolve by itself, at last most of farmland conversion could become economically and physically irreversible. So in order to control the progress, not only the income level that turning point occurs, but also the peak value of farmland conversion are both important signals for policy-makers. Thirdly, flattening the EKC curve can lower the peak value of farmland conversion, if government intervene the “tunnel through” the curve, exploring another path between upward and downward portions of EKC (See fig. 5). Several policies may be helpful to flatten out the curve. For instance, the removal of distorted development subsidies, and the enforcement of more secure property rights over farmland, and the imposition of environmental taxes on conversion will flatten the underlying EKC and perhaps achieve an earlier turning point. The peak value down from A to B in fig. 5 is induced together by these policies. Because

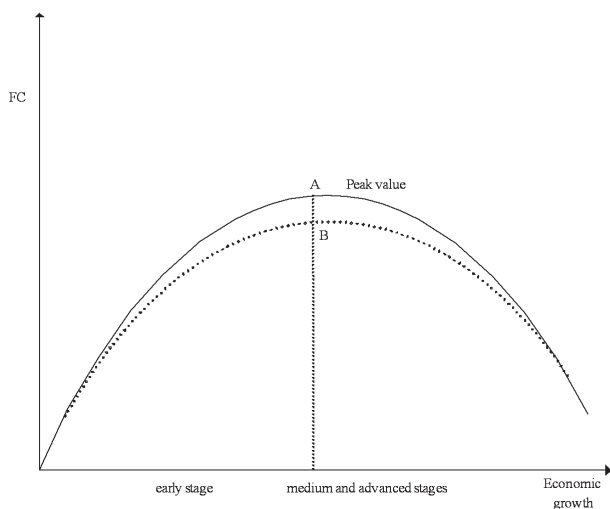


Fig. 5. Policy implication from flattening the EKC

market forces will ultimately determine the price of farmland, policies that allow market forces to operate are expected to be positive. The search for meaningful farmland protection is a search for ways to enhance property rights and markets. Government can depress the peak point through subsidizing land-saving industry, encouraging technological innovation in land use and so on. Fourthly, as the stage of economic growth among provinces is mostly different, correspondingly different regions won't follow the same EKC path. Therefore, more flexible standard on controlling farmland conversion may suit for them.

However, if we neglect the flaws of the empirical results and accept the EKC as the absolutely valid fact for the sake of the argument, the conclusion and all discussions will make no sense.

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