〈研究論文〉

An Econometric Analysis on Energy Intensity from the Perspective of Structural Change and Technical Progress
――Using Regional Panel Data of China

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Ⅰ. Introduction

Energy is an indispensible factor for economic growth. However, most of them are made of nonrenewable resources like oil and coal. Thus it's an inevitable duty for us to economize energy, i.e. increase the energy efficiency.

Recently, Low Carbon Economy (LCE), which pursues high energy efficiency by systematical planning, policy making and innovation to advance energy renewable technology and reduce the emission of greenhouse gas (Liu, 2010), becomes a heated issue in practical field, like legislation and management. But at the same time, relevant researches about low carbon economy spring up in many aspects such as Carbon Trust, clear energy, CO_2 emission, technology and so on.

Energy Intensity, an important issue in energy economics, aroused great interest in academic field, which depicts units of energy per unit of GDP (Liddle, 2012). In addition, Energy Efficiency is also an important index in energy economics, which depicts units of GDP per unit of energy. Apparently, Energy Intensity and Energy Efficiency are reciprocals. And this paper will concentrate on the issue of Energy Intensity and factors that impact on it relying on regional balanced panel data which has rarely employed in this field.

The following paper will be organized in this order: Part 2 will focus on literature review in this field. Before empirical study, we will go and lay some theoretical foundation for this issue. Basic analysis to data which is going to apply in models will be explained in Part 4. The main work occurs in Part 5, which creates panel data model to simulate the relationship between EI, structural change and technical progress. We will end this paper in Part 6 that planned to conclude the main idea and put forward some policies according to the results.

Ⅱ. Literature Review

China is the second largest economy in the world and the amount of energy consumption is tremendous in these years. With the development of the economy in the new millennium, the increase rate of energy consumption reached a very high level. For instance, it's 9.6% in 2006 (Shi *et al*, 2012). Empirical studies about China in energy economic field are also abundant.

As for the factors that influence the energy intensity or energy efficiency, plenty literatures have focused on economic structure and technical standards. However, according to the data they used, these papers can be classified as two categories: national data based study and regional data based

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study.

In the category of national data based study, Feng *et al* (2008) studied energy price, energy structure and economic structure about China systematically. It shows that the adjustments of energy price and energy structure haven't shown an obvious effect on energy efficiency. But economic structure change and technology progress can improve energy efficiency significantly. Han *et al* (2004) attribute energy intensity decrease to structural effect and efficiency effect. Their paper manifests energy intensity decrease in China mainly comes from efficiency improve in every sector, especially the secondary sector. Yang *et al* (2008) did empirical study on energy intensity using national data from 1978 to 2006. The result showed that economic structural change has a greater influence on energy intensity than technical progress, while increase in energy price has a limited impact on energy intensity, which is in accordance with Feng *et al* (2008).

In addition, Dong *et al* (2010) researched the factors that affect energy intensity in China using national data from 1985 to 2006. They put forward that increase the share of tertiary industry and strength technical innovation to increase energy efficiency. Liu *et al* (2010) proposed that increases energy efficiency by reducing energy consuming industries, accelerating technological progress and adjusting economic structure.

While In the category of regional data based study, researchers are also plentiful. Song *et al* (2012) created panel model to study the difference and tendency of energy intensity in every province. Their research shows that energy efficiency increase mainly attributes to energy intensity decreasing from 1995 to 2009. While economic structural change has limited effect. In fact, this conclusion is problematic. Just as we referred in Part 1, energy efficiency and energy intensity will strictly change in the opposite way, because one of them is the reciprocal of another. Thus the conclusion is wrong, strictly speaking. But from their paper, it's clear that "energy efficiency increase" they referred actually means energy efficiency increase in every sector, which is the so-called technical effect that we will concentrate on in the next part. Zhao *et al* (2013) studied human capital effect and technical progress effect on the energy efficiency using 28-provinces' panel data from 2000 to 2010. The result shows that improving productivity of human capital and developing energy－saving technology are effective ways to increase energy efficiency. Cao *et al* (2012) concluded that technological progress is the main factor for the decline of energy intensity.

The research of Dong *et al* (2012) is the closest to our study. They divided China into four regions: Northeast Region, East Region, Middle Region and West Region. Panel data model was also used to analyze the energy intensity. The result is: structural effect in Northeast Region is the largest and Middle Region is the least, and so as the technical effect. This paper, on the one hand, will show a more specific result, because we divided China into 8 regions; on the other hand, we will show our conclusion is slightly different with them, because our approach is different from theirs.

In China, the level of economic development, industrial structure and technical standards in different regions enlarged these years, so it's almost impossible to clarify the economic characteristics and developmental tendency of every region if we taking national data as a research object (Zhang and Qi, 2012). Usually, the result of these researches that based on national data will neglect the gap of regional development standards, thus some suggestions made according to their researches even fail to really take effect, like increase energy efficiency. For instance, this paper reveals that technical effects and structural effects vary in each region, thus the specific and effective ways that lead to lower energy intensity are also different.

Fortunately, many scholars realized this issue and try their best to improve it. A possible way to overcome this defect is applying provincial based data. This is also problematic. As we all know the dividing of these provinces is based on historical and geographic factors, rather than economic standards. In addition, provinces based data causes non-stationarity easily, which makes it inconvenient to estimate relevant coefficients. Thus taking them as research objects are also questionable. As a way to agglomerate it, some scholars divide China into 3 or 4 parts (Dong *et al*, 2012). However, this method also renders problem because the standard of dividing is mainly geographical, although it takes economic standards in various regions into account.

Facing these defects, this paper takes an eclectic way— dividing China into 8 regions listed in Table (2.1) which is in accordance with 2007 Input-Output Table[ii].

Table (2.1): Region Dividing[iii]

Region	Province
Northeast	Heilongjiang, Jilin, Liaoning
Jing-Jin	Beijing, Tianjin
North Coast	Hebei, Shandong
East Coast	Jiangsu, Shanghai, Zhejiang
South Coast	Fujian, Guangdong, Hainan
Middle	Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi
Northwest	Inner Mongolia, Shannxi, Ningxia, Gansu, Qinghai, Xinjiang
Southwest	Sichuan, Chongqing, Guangxi, Yunnan, Guizhou, Tibet

Ⅲ. Theoretical Framework

As we described in Part 1, the definition of Energy Intensity is units of energy per unit of GDP, that is:

$$EI=\frac{\text{Energy Consumption}}{GDP} \quad (3.1)$$

In order to study the effect of technical progress and structure change on EI, we can rewrite it as (Yang, 2013; Han et al, 2004):

$$EI=\frac{GDP*R_1E_1+GDP*R_2E_2+GDP*R_3E_3}{GDP}$$
$$=\sum R_iE_j \quad (i=j=1,2,3) \quad (3.2)$$

In equation (3.2), R_i (i=1,2,3) and E_j (j=1,2,3) denotes the share and EI in every sector. It's clear that the overall EI equals the weighted average of EI. And it was determined by economic structure and energy intensity of each sector. However, with the same methodology in equation (3.2), we can divide E_j into:

$$E_j=\sum R_mE_n \quad (m=m=1,2,3\cdots\cdots) \quad (3.3)$$

In equation (3.3), R_m represents the share of every "sector", say automobile sector and petroleum sector, while E_n denotes their corresponding energy intensity. Substituting (3.3) into (3.2), we can get:

$$EI=\sum(R_i\sum R_mE_n) \quad (i=1,2,3;\ m=n=1,2,3\cdots\cdots) \quad (3.4)$$

We can divide (3.4) continually and endlessly. In the end, the economy will be divided into plenty of the minimum units, like an electricity water heater. In this situation, energy intensity has nothing to do with structural effect, and only Energy Intensity in this "sector" plays a role. Which determinant decides the energy intensity of this "minimum unit"? Without any doubt, it's technologic standard that decides its energy intensity. Its EI will decline if technical progress has been made.

Roughly speaking, E_j in equation (3.2) can be explained by technology if we regard each sector as an undividable minimum unit, i.e.:

$$EI=\sum R_iT_j \quad (i=j=1,2,3) \quad (3.5)$$

In equation (3.5), T_j means technology in every sector. Hence, the overall EI was determined by structural change and technical progress.

Ⅳ. Data

Just as presented in Part 2, the existing literature has some flaws when research the factors that influence the energy intensity, which may lead to improper result and policies that fails to take effect. Facing these defects, this paper re-divides China into 8 regions according to economic standard and focuses on doing empirical research again using classical methods—regional panel data.

Before econometric analysis, it's necessary to view the basic information of data we planned to use in the next part. In this paper, we use relevant data (industrial structure, patent and energy intensity) from 1999 to 2012 in these 8 regions to study the technical effect and structural effect on energy intensity.

The explained variable is energy intensity. Firstly, we collect real GDP of every province base on the price standards of 2010 from China Statistical Yearbook. Then, we find data about energy consumption of every province in terms of standard coal from China Energy Statistical Yearbook. Finally, according to equation (3.1), it's possible to calculate energy intensity in every province.

There are two explanatory variables: structural change and technical progress. As for structural change, we select the share of the secondary sector, because China is an emerging economy and its share of the secondary changes obviously and regularly in almost every province, which makes it convenient to create panel data models.

Generally speaking, educational expenditure and patents are two indexes that depict technical progress, which are from the perspective of "input" and "output". As we all know, educational expenditure doesn't necessarily lead to corresponding technological progress. Moreover, we should transform nominal educational expenditure into real educational expenditure if we planned to use input method, which may render problems when processing data overly. Here, we use output method—patent, which it much more approximates to real technical standards. But it doesn't mean output method is perfect, because it's not unusual that a manager keeps new and advanced energy-saving technology as a business secret, rather than apply a patent, but we cannot choose a better one. Given all defects and flaws, we choose patents that come from China Technology Statistical Yearbook as the index of technical progress.

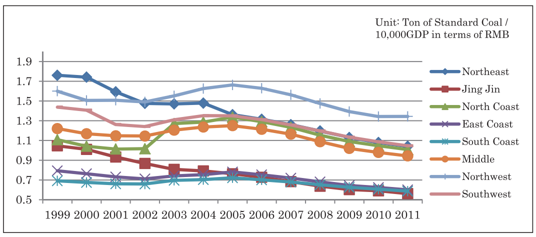
In addition, for statistical reasons, it's hard to collect the whole relevant data about Tibet. Moreover, Tibet's economy only plays a small role in China, so we have to give it up and collect data of the rest provinces.

1. Energy Intensity

Energy Intensity varies from region to region, but they are still high compared to developed—economics, say it reached ８ dollars per unit of oil in Japan, while it's just ３ dollars in China at the same time[iv]. From Figure (4.1), it's clear that energy intensity developed areas, like South Coast and East Coast, are comparatively lower. While the western lands like Northwest and Southwest suffer from high energy intensity. Generally speaking, the higher standards the economy developed the lower energy intensity it has.

But there are some exceptions. First, Northeast and North Coast are two comparatively developed economies, but they still suffer from high energy intensity. The reason is that there are more energy consuming industries, like steel industry and coal industry, in this area, thus the EI is very high, although they are developed economies.

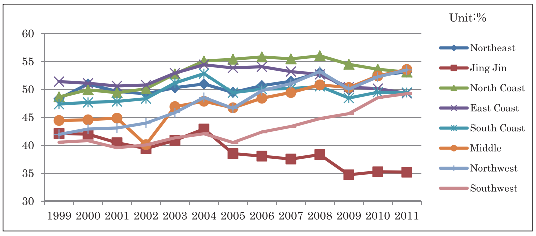
Figure (4.1): Energy Intensity[v]



2. Economic Structure

From the experience of the world, the share of the secondary sector will increase as the economy growth, while it will decrease when the economy develops a step further. From figure (4.2), we can see there shows a great difference in the share of the secondary sector in each region. On the whole, the less developed areas show a rapid increase rate, like Middle Region and Southwest Region, while the developed regions reflect a slower increase rate or slightly decline over these years, like East Coast and Northeast Region. And there are some highly developed economies even show a speedy decline, say Jing-Jin. What's more, we can see that they almost converge to 50% except Jing-Jin Region from 1999 to 2011, but we can make a prediction that they will decline in the following years.

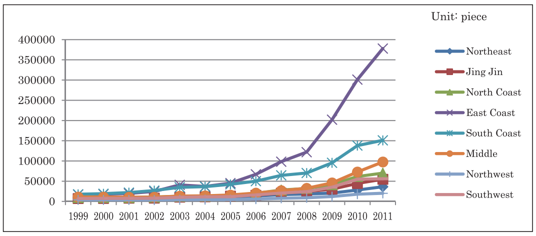
Figure (4.2): Share of the Secondary Sector[vi]



3. Technological Change

As for patents, from 1999 to 2011, we can see that these regions started almost at the same level, but diverged in 2002. From then on, the quantity in South Coast and East Coast takes off, while other regions slightly increased, see Figure (4.3).

Figure (4.3): Patent[vii]



According to the State Intellectual Property Office of P.R.C, patents can be classified into 3 types: Utility Patent, Design Patent and Invented Patent[viii]. However, Utility Patent and Design Patent are much easier to be patented, which almost occurs in light industry. Hence, in East Coast and South Coast where are characterized with light industry, it's not unusually that the amount of patent increases exponentially when the economy rockets up.

Ⅴ. Econometric Model

This paper aims to researches Energy Intensity using panel data of every region from perspective of technical progress and structural change. In addition, Eviews 8.0 is the professional tool we planned to use.

1. Unit Root Test

Just as it stated in Part 3, Energy Intensity is related to technical standards and economic structure, which we called technical effect and structural effect. Thus, this paper sets the panel data model as:

$$\log(EI_{it})=C_{it}+\alpha IN_{it}+\beta\log(PA_{it})+\theta_i+\rho_t+\varepsilon_{it} \qquad (5.1.1)$$

In Equation (5.1.1), i and t represent entity (each province of a certain region we studied) and time (from 1999 to 2011). IN is the share of the secondary sector, while log(EI) and log (PA) denote Energy Intensity and Patent in logarithmic form[ix]. In addition, ρ_t and θ_i represent terms of unobservable fixed effects of each year and every entity, and ε_{it} is normal error term.

However, it's better to test the unit root, because it can avoid Spurious Regression before estimation. Table (5.1.2) is the result of ADF Test:

From Table (5.1.2), we can see that the variables are non-stationary at I(0), while these series are first-order integrated (I (1)). Thus, in order to avoid spurious regression (Granger and

Table (5.1.2): Result of ADF Test[x]

Region	log (EI)		IN		log (PA)	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
National	42.19	101.0**	21.28	214.5**	0.90	130.5**
Northeast	1.26	21.03**	1.78	29.36**	0.02	19.10**
Jing－Jin	1.77	9.94*	6.51	13.45**	0.00	10.97*
North Coast	2.04	15.63**	1.34	12.11*	0.01	12.51**
East Coast	0.89	14.22*	6.34	23.82**	0.01	18.16**
South Coast	2.19	19.75**	1.10	18.23**	0.28	18.24**
Middle	3.43	23.49**	1.54	44.51**	0.13	33.06**
Northwest	19.09	31.64**	0.84	59.08**	0.42	24.72*
Southwest	8.33	19.34*	1.81	30.45**	0.03	22.46**

Table (5.1.3): Result of Various Tests for National Model[xi]

	Pooled	Cross-Section		Period		Best Model
Effects	N&N	F&N	R&N	N&F	N&R	F&N
C	0.814***	0.801***	0.805***	0.884***	0.814***	0.801***
	(8.20)	(8.03)	(4.58)	(23.73)	(2.83)	(8.03)
IN	0.023***	0.008***	0.008***	0.022***	0.023***	0.008***
	(11.87)	(8.01)	(3.08)	(17.92)	(4.11)	(8.01)
Log(PA)	−0.216***	−0.128***	−0.134***	−0.223***	−0.216***	−0.128***
	(−21.69)	(−14.25)	(−8.11)	(−22.77)	(−7.36)	(−14.25)
Observations	390	390	390	390	390	390
Adjusted R-squared	0.56	0.94	0.43	0.55	0.56	0.94
F-statistics		93.75		0.50		93.75
(Pooled vs Fixed)		[0.00]		[0.91]	[0.00]	
F-statistics			10.74		25.16	
(Fixed vs Random)			[0.00]		[0.00]	

Newbold, 1974), it needs to employ Engle－Granger Two-Step Method to test co-integration (Engle and Granger, 1987).

The first step of Engle－Granger Two-Step Method is estimation coefficients in Equation (5.1.1) by using ordinary least squares (OLS) generally, and then tests ε_{it} for stationarity with something like a Dickey－Fuller test and Phillips-Perron test.

(1). Estimation

Applying these data, we tested and analyzed several models using Eviews 8.0, like Cross-Section Fixed/Random/None Effects and Period Fixed/Random/None Effects for every region. Taking national data as an example [see Table (5.1.3)], we tested Fixed and Random Effect for Cross-Section, the result shows Fixed Effect is better. With the same method, it shows the both Random and Fixed Effect aren't suitable for the Period, which implies Cross-Section Fixed Effect is the best for national model.

As for other regions, like Jing-Jin and Northeast, the method is the same. And the estimating results are shown as Table (5.1.4):

We found that estimation in Northeast Region, which the sign of technical effect goes against common sense and theory framework we stated above, is abnormal and infeasible, so we

Table (5.1.4): Estimation Result[xii]

Region	Effects	C	LN	Log(PA)	Observations	Adjusted R－squared
National	F&N	0.801*** (8.03)	0.008*** (8.01)	－0.129*** (－14.25)	390	0.94
Northeast	N&F	－0.780*** (－6.46)	0.003*** (3.81)	0.108 (11.99)	39	0.92
Jing－Jin	F&N	1.868*** (8.67)	0.007*** (2.64)	－0.272*** (－15.31)	26	0.95
North Coast	F&N	－1.100*** (－3.20)	0.041*** (6.74)	－0.097*** (－7.40)	26	0.93
East Coast	F&N	－0.848*** (－3.37)	0.022*** (5.53)	－0.060*** (－8.42)	39	0.78
South Coast	R&N	－0.161*** (－8.23)	0.008*** (3.48)	－0.064*** (－5.36)	39	0.49
Middle	F&N	0.896*** (10.40)	0.005*** (5.12)	－0.125*** (－9.02)	78	0.94
Northwest	F&N	0.805*** (6.60)	0.009*** (2.93)	－0.113*** (－4.93)	78	0.92
Southwest	F&N	1.230*** (6.32)	0.008** (2.24)	－0.167*** (－8.25)	65	0.93

Table (5.1.4): Unit Root Test for Resid ε_{it}[xiii]

Region	National	Jing-Jin	North Coast	East Coast	South Coast	Middle	Northwest	Southwest
Result	155.30**	14.27**	14.81**	18.73**	13.02*	38.10**	53.84**	32.60**

Table (5.2.1): Structural Effect Coefficients Ranking

Coefficient	0.005	0.007	0.008	0.008	0.008	0.009	0.022	0.041
Region	Middle	Jing-Jin	South Coast	National	Southwest	Northwest	East Coast	North Coast

have to exclude this region before we enter into the second step of Engle－Granger Two-Step Method. However, coefficients of Structural Effect and Technical Effect in other regions can pass T-statistical test at least at 5% significant level, thus they are effective estimations.

(2). Unit Root Test for Resid ε_{it}

We tested ε_{it} of every effective equation above. The result is listed in Table (5.1.4) which shows that ε_{it} is zero-order integrated (I(0)), thus we can make sure that equations above are Co-integrated Equations.

2. Result and Analysis

Through unit root test, it proves that estimations in Table (5.1.3) are effective except Northeast Region. It's clear that structural effects and technical effects vary in different regions. Comparing these coefficients, we can get Table (5.2.1) and Table (5.2.2), which ranks these coefficients in an ascending order:

On the whole, it reveals that Structural Effect (The

Table (5.2.2): Technical Effect Coefficients Ranking

Coefficient	−0.272	−0.167	−0.129	−0.125	−0.113	−0.097	−0.064	−0.060
Region	Jing-Jin	Southwest	National	Middle	Northwest	North Coast	South Coast	East Coast

Secondary Sector) has a negative effect on Energy Intensity, which means increasing the share of the secondary sector raises energy intensity, i.e. declines energy efficient. However, Technical Effect shows a positive effect on Energy Intensity, which means more Patents will decrease energy intensity, i.e. promote energy efficiency. This result is in according with some literature listed in Part 2.

But it also discloses the differences in these regions. As for Structural Effect in Table (5.2.1), these co-integrated equations also show that: Structural Effect is the least significant in Middle Region, while it's the most significant in North Coast Region. From Figure (4.2), we found that the share of the secondary sector in coastal areas is comparatively higher than other regions, while regions with lower share of the secondary industry shows a weaker relationship with energy intensity. Thus, in general, a higher share of the secondary sector denotes a stronger linkage between energy intensity and structural change, i.e. the structural effect is significant.

As for Technical Effect, in Table (5.2.2), these co-integrated equations also show that: Technical Effect is the least significant in East Coast Region, while it's the most significant in Jing-Jin Region. From Figure (4.3), we found that the amount of patents in coastal areas is comparatively higher than other regions, while regions with lower quantity of patents show a weaker relationship with energy intensity. Thus, in general, we can conclude that: a larger amount of patents means a weaker linkage between energy intensity and technical progress, i.e. the technical effect is less significant.

Ⅵ. Conclusion and Policy

This paper studied China's Energy Intensity and its determinant factors: structural change and technical progress. Unlike existing literature that usually taking the national data or provincial data as a research object, we divided China into 8 regions that is in accordance with I-O Table of 2007 and use these regional data to do empirical research.

Firstly, we tested unit root for these time series; the result shows that they are all first-order integrated (I(1)). Then, employing Engle−Granger Two-Step Method, we found these equations are co-integrated equations, although the original series are non-stationary. Finally, we concluded that these estimations are effective.

Through these equations, we obtained structural effect and technical effect in different regions, which reveals that structural change has a negative effect on energy intensity, while technical progress shows a positive effect on it. The specific coefficients of these regions ranked in Table (5.2.1) and Table (5.2.2), which discloses that North Coast has the highest Structural Effect, while Middle ranks the lowest. On the other hand, Jing-Jin has the strongest Technical Effect, while East Coast scores the weakest.

We also generalized that: 1) in general, a higher share of the secondary sector denotes a stronger linkage between energy intensity and structural change, i.e. the structural effect is significant; 2) a larger amount of patents means a weaker linkage between energy intensity and technical progress, i.e. the technical effect is less significant.

In addition, the coefficients in each region are different, which provide us with some policy implications. According to the result of this paper, it's possible for policymakers to conduct effective actions to achieve an economy with higher energy efficiency. For example, it's better for East Coast to conduct "Structural Policy" to achieve high energy efficiency, while it's "Technical Policy" for Jing-Jin Region. And for some areas with lower patents and higher share of the secondary sector (less developed areas), like Northwest, they can conduct flexible ways to achieve low energy intensity, i.e. "Structural Policy" and "Technical Policy" are significant.

Finally, we also calculated the relevant coefficients based on national data and it shows differences in comparison with that based on regional data, which suggests policies based on national data aren't necessarily suitable for each region. Hence, policies should vary according to the specific state of each region.

Note:

i): Hunan Province and Hubei Province are divided by Dongting Lake; Henan and Hebei are divided by Yellow River.

ii): It refers to China Multi-Regional Input-Output Models 2007. In this book, it divides China into 8 regions according to economic standards and geographic relationships.

iii): Source: China Multi-Regional Input-Output Models 2007.

iv): Data come from World Bank WDI database.

v): Source: China Energy Statistical Yearbook, various years and China Statistical Yearbook, various years.

vi): Source: China Energy Statistical Yearbook, various years.

vii): Source: China Statistical Yearbook on Science and Technology, various years and China Statistical Yearbook, various years.

viii): It refers to State Intellectual Property Office of P.R. C (http://www.sipo.gov.cn).

ix): Here, in order to facilitate estimation in Eviews 8.0, we take the logarithmical form of EI and PA as an index to depict Energy Intensity and Patent.

x): * and ** denotes significant at the 5 percent and 1 percent level.

xi): 1) *, **and *** represent significant at the 10%, 5% and 1% levels. 2) N, F and R denote None, Fixed Effect and Random Effect, for instance, F&R mean Cross-Section Fixed and Period Random Effect. 3) Values in the ( ) are corresponding T-statistics used robust standard error for panel regressions. 4) Values in the [ ] are corresponding probabilities.

xii): *, **and *** represent significant at the 10%, 5% and 1% levels.

xiii): * and ** denotes significant at the 5 percent and 1 percent levels.

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