Electricity and Agricultural Development in Punjab

Atsushi Fukumi[1]

Introduction

While India attracts investment from all over the world as a huge emerging market, its insufficient infrastructure has repeatedly been pointed out as a bottleneck for further industrialization. In particular, there is an urgent need to improve the quality of power supply, and several drastic reforms have been implemented in the power sector, such as the unbundling of the State Electricity Boards (SEBs), the establishment of an electricity regulatory commission (ERC), and the enforcement of the Electricity Act 2003. However, the most crucial problem in the sector, the deteriorated financial status of state power distribution utilities, still persists, and they remain far from achieving their targets.

One of the biggest factors contributing to the deterioration of power utilities' finances is the distorted tariff structure, under which agricultural users enjoy preferential electricity tariffs that are much lower than the cost of power supply. During the period of the Green Revolution, which began in the late 1960s, electricity contributed to the spread of high yield varieties as an essential form of energy for tube well irrigation. It is suggested that this flat-rate tariff system for electricity effectively worked as a subsidy for farmers who introduced this water-intensive technology (Shah, 2009). However, the rapid increase in power consumption expanded the total amount of the subsidy and resulted in the de facto bankruptcy of power utilities, which in turn reduced the expenditure toward investment and maintenance of power infrastructure, resulting in the poor quality of power supply. It is also suggested that power subsidies in the form of flat-rate tariffs promoted overconsumption of ground water and a decline in the ground-water level, especially in the northwestern and southern parts of the Indian subcontinent. However, it should be noted that, while agricultural power subsidies have been criticized from the viewpoint of their effect on the finances of power utilities, they have also been recognized as drivers of agricultural growth.

In this paper, following the situation, we empirically analyze the long-term relationship between power consumption and agricultural output in Punjab in order to evaluate the role played by agricultural power consumption and power subsidies. The results of a Johansen test using time series data from 1967 to 1999 in Punjab suggest that there exists a cointegration relationship between the production of food-grains and agricultural power consumption. However, a Granger causality from electricity consumption to food-grain production is not found, although an opposite causality is found, implying that both electricity and subsidies were used in a wasteful manner in the process of agricultural development in Punjab.

The remainder of this paper is organized into four sections. In section 2 we briefly explore the relationship between ground-water irrigation and electricity during the Green Revolution. In section 3 we investigate the long-term relationship between electricity consumption and agricultural

[1] fukumi@econ.u-hyogo.ac.jp

production using a Johansen cointegration test and a VEC Granger causality test. Section 4 concludes the paper.

2. Electricity and the Green Revolution in Indian Agriculture

2.1 The Green Revolution and the Role of the Tube Well

India's Green revolution started in the late 1960s following two droughts in the northwestern states including Punjab, Haryana, and Uttar Pradesh, by introducing high-yielding varieties of wheat and, a few years later, those of rice. Agricultural policy soon after independence focused on land reforms and the organization of agricultural cooperatives, but in the early 1960s, prior to the Green Revolution, a new agricultural strategy of promoting new technologies was adopted. From figure 1, which shows long-term rice and wheat production trends, we can see the production of wheat starting to increase drastically in the late 1960s owing to the rapid diffusion of a high-yielding Mexican semi-dwarf wheat variety. As for rice production, we can see the start of an increasing trend a short while after the jump in wheat production, indicating that the wave of new technology had reached the eastern rice-producing states after the introduction of high-yielding rice in the northwestern states in 1970s. As a result, India achieved self-sufficiency in food grain production and an improvement in its citizens' nutritional status by the late 1970s. It should be noted that this freed the country from an undesirable pattern of balance of payment crises following a sharp increase in food-grain imports as a result of droughts. Thus, it is safe to say that the Green Revolution was an event of great significance not only in terms of reducing poverty but also stabilizing the macro economy, and underground irrigation played a crucial role in this process. It is often suggested that (a) high-yielding varieties and chemical fertilizers, (b) irrigation, and (c) food procurement policies were the essential elements contributing to India's Green Revolution, and the rapid expansion of ground-water irrigation using tube wells after the late 1960s was especially important to the diffusion of high-yielding varieties. From the long-term trend of irrigated land in figure 2, we can see that the area of land irrigated by tube wells started expanding rapidly in the late 1960s and eventually exceeded the area of land under irrigation by canals, which were the main source of irrigation until the late 1990s. The expansion of tube-well irrigation realized sustainable water supply to individual farmers, which supported India's Green Revolution[2].

2.2 Electricity and Agricultural Development

In the beginning, when tube wells started being used for irrigation, diesel tube wells were installed, but gradually, electric tube wells became common in electrified villages. In Punjab, the share of electric tube wells overtook the share of diesel ones to reach 80 percent of the total during

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[2] Shah (2009) pointed out that diffusion of ground water irrigation contributed to poverty reduction in rural areas through the following economic changes: (a) the expansion of cultivated land, (b) an increase in agricultural production and a hike in labor demand and wages, (c) an increase in income owing to changes in cropping patterns, (d) the development of the water market and a decline in water fees, as well as social changes such as (e) an easing of social conflict in dry areas, and (f) the reduction in inequality stemming from traditional hierarchies.

the 1990s[3]. Figure 3, which shows the number of electric pump sets and the amount of power consumption, demonstrates the steady diffusion of pump sets with the expansion of agricultural power consumption[4]. Thus, after this period, electricity became a crucial input, and it should be noted that a flat-rate tariff system for electricity was introduced for agricultural consumers and took on an important role. During the initial period of electrification, relatively higher tariffs were imposed on agricultural consumers compared with industrial and domestic consumers. However, Punjab introduced a flat-rate tariff in 1968, which triggered its adoption in several other states such as Uttar Pradesh in 1974, Haryana in 1978, Maharashtra in 1978, Rajasthan in 1979, and so on. In the background to the spread in this flat-rate tariff system, Shah (2001) and Shah et al. (2004) pointed out, were the ballooning costs related to tariff collection in less populated rural areas and controlling the malpractice of meter readers, which burdened the financial status of utilities. As a result, farmers became able to use electricity at a much lower price than the cost of power supply, even free of charge in several states, thereby effectively receiving an irrigation subsidy. It is, therefore, safe to say that an agricultural power subsidy in the form of a flat-rate tariff, which reduced the cost of usage of electric tube wells, made a certain contribution to the process of India's Green Revolution by promoting the diffusion of ground water irrigation.

However, the amount of agricultural power consumption differed from state to state. From figure 4, which shows the amount of annual agricultural power consumption per acre of irrigated land, we can see that southern states like Maharashtra (5133kWh), Tamil Nadu (4338kWh), Karnataka (3884kWh), and Andhra Pradesh (3734kWh) are big consumers of agricultural power, followed by western and northwestern states like Gujarat (3150kWh), Haryana (2873kWh), Punjab (2446kWh), and Rajasthan (1987kWh), while consumption in eastern states like West Bengal (610kWh), Bihar (128kWh), and Odisha (137kWh) is marginal. On this issue, figure 5, which shows the state-wise distribution of diesel and electric irrigation pump sets, suggests that the states differ in terms of the number of tube wells and the amount of agricultural power consumption. For example, Bihar has the largest number of irrigation pump sets, but most of them are diesel-run, while farmers in Punjab are heavily dependent on tube wells, 90 percent of which are electric. Shah (2009) geographically divides the Indian subcontinent into three zones based on (a) metering, leading to dieselization, (b) de-electrification, leading to dieselization, and (c) subsidization, suggesting that electricity policies have led to the current differences in agricultural power usage, number of tube wells, and financial status of power utilities. Figure 6, which shows each state's share of agricultural power consumption in India, reveals that the 10 largest states together account for 95 percent of the total consumption in India, and that there exists a close relationship between the power sector and agricultural development[5] especially in these states.

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[3] See Government of Punjab (2015) for details.

[4] The decline in power consumption toward the end of the 1990s will be investigated in Section 3.

[5] See Shah et al. (2004) and Shah (2009) for comprehensive studies on the issue of the connection between irrigation, ground water, and energy.

2.3 The Financial Deterioration of Power Utilities[6]

After electricity became a crucial input for agriculture, and flat-rate tariffs were introduced, financial problems began to emerge for state power utilities. During the 1980s, since the expansion of agricultural power consumption was directly related to the expansion of agricultural power subsidy, this resulted in the financial deterioration of the state electricity boards in various states. From figure 7, which shows the trend of commercial losses in the power sector due to losses related to agricultural power consumption, we can see that power supply to the agricultural sector has been generating huge commercial losses, while profits from other sectors compensate for it only partially[7], resulting in the financial deterioration of utilities. In the 1990s the commercial losses of power utilities in India reached 10 percent of the Gross Fiscal Deficit of all state governments. More importantly, the issue of financial deficits in the power sector should be considered in the context of the soft budget problem shared by all public utilities. The SEBs being state government departments, their commercial losses can be financed eventually, so the incentive for rational cost management is essentially weak, and serious problems such as power theft, non-payment of tariffs, and huge transmission and distribution losses have been neglected. It can be said, therefore, that the introduction of subsidy policies for agricultural consumers enhanced the structural problem of SEBs as public utilities.

The stressed financial status of SEBs reduced expenditure toward investment and maintenance, which directly resulted in unstable power supply. Simultaneously, poorly maintenance of infrastructure lowered the efficiency of power generation, transmission, and distribution, thereby worsening the financial problem of SEBs and creating a vicious circle. Besides, the issue of wastage of a scarce resource can be raised, as farmers do not have any incentive to limit their power consumption under the flat-rate tariff system. In recent years, a decline in the groundwater level has become a critical issue in Punjab, Haryana, Rajasthan, and Tamil Nadu, and the overexploitation of groundwater under distorted tariff structures is pointed out as the background to this problem. These problems have been left to worsen because agricultural power subsidies are an effective political tool for buying the vote of farmers during state assembly elections[8], which makes the revision of tariffs almost impossible. Therefore, though it has been the main issue in power sector reforms since the 1990s, rationalization of the tariff structure is still difficult to implement for political reasons, and power distribution utilities still report huge commercial losses. In other words, agriculture power subsidies may have supported the Green Revolution, but left a negative legacy that persists.

3. Agricultural Production and Electricity Consumption – Cointegration and Granger Causality

3.1 The Analysis Framework

In this section, we investigate the long-term relationship between agricultural production and

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[6] On the financial issues of the power sector and its reform, see Battahcharyya (2005), Planning Commission (2013), and Fukumi (2014), (2016).

[7] Tariffs for industrial consumers are set higher than the costs in order to compensate for the loss from agricultural consumers.

[8] Dubash and Rajan (2001) find the root of the power tariff politicization problem in the Andhra Pradesh state assembly election campaign.

electricity consumption in Punjab. It is assumed that if a positive impact of electricity consumption on agricultural production can be found, it would be safe to say that agricultural power subsidies played a certain positive role in agricultural growth despite their negative impact on the power sector. There already exist a number of previous empirical studies on the relationship between energy and production in the fields of energy and environment economics[9]. Based on Chontanawat et al. (2008), which presents a procedure for systematic analysis along with a comprehensive survey of the literature, we conduct our investigation as follows: (1) testing the stationarity of the variables, electricity consumption and agricultural production, through ADF tests (if both the series are I(1), we can test for cointegration between series integrated of the same order); (2) testing for cointegration between GDP and ELE using the Johansen test with the lag selected by the AIC (the existence of cointegration rules out Granger non-causality); (3) testing the direction of causality using VECM (Vector Error Correction model) Granger causality tests[10] (with this procedure, we will find the direction of causality).

3.2 Data

As a proxy for agricultural production, we employ food-grain data[11]. Figure 8 shows that both the production of food grains and agricultural power consumption in Punjab are fundamentally inclined to increase. However, it should be considered that at the end of 1990s, agricultural power consumption fell drastically, in line with the overall national trend as seen in figure 3. This may reflect an outcome of the full activation of power sector reforms at that time, namely, the precise reporting of the amount of power consumption, which was previously over-reported. Of course, it is also possible that determined reform efforts, including the establishment of state electricity regulatory commissions (SERC), the revision of tariff structures, and improvement in metering, put a brake on the continued expansion of agricultural power consumption. On the other hand, we should consider that (a) state electricity boards had the incentive to over-report because commercial losses stemming from agricultural power supply could be compensated by state finances, so (b) it is highly likely that a certain portion of transmission and distribution losses due to malpractices such as power theft had been reported as "agricultural power consumption"[12]. In fact, most of the states with large agricultural power consumption showed a decline in transmission and distribution losses soon after the introduction of flat-rate tariffs and a jump in these losses toward the end of the 1990s, when states started to engage in power sector reforms seriously[13].

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9 The causal relationship between energy consumption and economic growth has been studied since the 1970's. Payne (2010) surveyed the literature and showed that empirical results were mixed. Murry and Nan (1996), Gosh (2002), and Chen et al. (2007) use data from India to analyze the relationship between electricity consumption and GDP growth.

10 More precisely, Chontanawat et al. (2008) conducted a Granger causality test using a VAR model despite the lack of cointegration.

11 Food grains include rice, wheat, corn, coarse grains (sorghum and millet), and pulses (beans, dried peas, and lentils). In Punjab, rice and wheat account for 90% of food grains.

12 See Shah (2001) and Shah et al. (2004) for details.

13 In addition to the two states shown here, this pattern is obvious in Andhra Pradesh, Rajasthan, Uttar Pradesh,

On this point, we will take up data from Maharashtra, which shows the most obvious pattern in addition to Punjab, for consideration. Figure 9 and Figure 10 show the trends of agricultural power consumption, transmission, and distribution losses and the ratio of transmission and distribution losses in Maharashtra and Punjab, respectively. In Maharashtra, a flat-rate tariff was introduced in 1978, following which transmission and distribution losses declined to 15.46% in 1985 from 18.32% in 1978. These losses remained in the 16-18% range till the late 1990s, but jumped to 29.2% in 1999. In this year, agricultural power consumption decreased by 35% while transmission and distribution losses increased by 77% compared with the previous year. A similar pattern can be found in Punjab, namely that three years after the introduction of the flat-rate tariff, transmission and distribution losses declined in 1972, hovering at around 18% for decades, but suddenly increasing to 26.58% in 2000. In this year, agricultural power consumption decreased by 33% and transmission and distribution losses rose by 49% compared with previous year. Moreover, an interesting point found in both states is that the sum of the two series, agricultural power consumption and transmission and distribution losses, shows a gentle rise while each series viewed separately shows a drastic change. The changes in the two series almost canceled each other out. It is safe to say, therefore, that the drastic change in the amount of agricultural power consumption at the end of the 1990s can be explained as one of the outcomes of power sector reforms, which required precise reporting of the amount of consumption and losses[14], especially if we also take into consideration that (a) in the year reporting drastic change in agricultural power consumption, the annual harvest was average, so that one cannot attribute the decline in power consumption to a drought, and (b) though the ratio of transmission and distribution losses can change in the long term, these changes tend to take place in a gradual manner.

Following this discussion of power consumption statistics, we handle this problem as follows. First, after estimating and removing the over-reported amount of agricultural power consumption, we employ the modified series as well as the original series for our analysis. To estimate the over-reported values, we use the figures for the ratio of transmission and distribution losses from the year before they fell, following the introduction of flat-rate tariffs and the year when they jumped, following reforms. Assuming that the ratio changes only gradually as a trend through the period, we calculated the missing portion of transmission and distribution losses that had instead been over-reported as agricultural power consumption and subtracted this portion from agricultural power consumption. Figure 11 demonstrates the results following the adjustment using data from Punjab. It is estimated that power consumption was over-reported by up to 40 percent for a few years before its sudden decline in the late 1990s. Figure 12 presents both the original and modified series of the growth rate of agricultural power consumption against the growth rate of food grain production. We can see a slight change in the growth rate of agricultural power consumption. Next we take up data for the years 1967-1999 for analysis. Taking into account the possibility of a structural change, we do not

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Karnataka, and Madhya Pradesh.

[14] Both Maharashtra and Punjab established a State Electricity Regulatory Commission (SERC) in 1999.

include the series after the year 2000. This is reasonable as our analysis only includes the period of the Green Revolution in Punjab, in an effort to find the role of power on agricultural development.

3.3 Estimation results

Table 1 shows the results of a unit root test on the logarithms of the levels and the first differences of each series used in the analysis. Based on the statistics of DF-GLS, ADF, and Phillip-Perron, the null hypothesis of a unit root can not be rejected, while it can be rejected at the 5% level of significance on the first difference of all series except for one result of DF-GLS on the original series of agricultural power consumption. As a whole it is indicated that if all series are I(1) in nature, cointegration tests can be applied to all series.

Table 2 represents the results of the Johansen cointegration test between agricultural power consumption and food grain production. As both results using the original and modified series of agricultural power consumption indicate, cointegration is accepted since both the trace and maximum-eigenvalue test statistics indicate one cointegrating vector at the 1% level of significance. Based on the result, which suggests that a long-term relationship exists, we employ a VECM Granger causality test to examine the direction of causality. The results reported on table 3 indicate unidirectional Granger causality running from food grains to the modified series of agricultural power consumption at 5% of significance, while the null hypothesis of no Granger causality from power consumption to food grains cannot be rejected in either result using the original or modified series of agricultural power consumption.

Thus, our estimation results present an impact in the form of an expansion in agricultural power consumption due to an increase in food-grain production, while no contribution to food grain production from agricultural power consumption can be found. This result has the following two implications. First, an over-consumption of power in the agricultural sector is quite possible. The expansion of cropped area of high yield varieties expanded the demand for electricity by farmers, but the expansion of agricultural power consumption did not necessarily lead to an increase in agricultural production at the same pace, and electricity has been over-consumed and wasted under the flat-rate tariff system. Though our result does not directly deny the contribution of agricultural power subsidies to agricultural growth in Punjab, it does suggest that they accelerated the overexploitation of energy. Secondly, the impact of ground water decline should be considered. The second implication is that as the water tables drop at an alarming rate in Punjab, the energy required for irrigation per unit of agricultural production also increase. Thus, our estimation results, which did not find the causality from electricity consumption to agricultural production, might be affected by the ground water situation.

4. Conclusion

The aim of this paper was to analyze the role of power subsidies on agricultural development by investigating the relationship between agricultural production and electricity consumption in Punjab.

The results of the cointegration and Granger causality tests using two series of agricultural power consumption taking into account the possibility of over reporting, suggested that an increase of agricultural production leads to greater electricity consumption, but no reverse causal relationship was found. These results do not deny the contribution of electricity to production, but imply the possibility of over-consumption stemming from agricultural power subsidies in the form of flat-rate tariffs. Considering the small number of quantitative studies in the literature, we can say that the findings of this paper can help to evaluate the role of power subsidies, which is a controversial issue. Before closing this paper, we should point out parts of our analysis in need of further refinement. First, we include only two variables, and our analysis could be expanded to include other variables such as the ground water table, requested energy per tube well, and so on. Second, in addition to food grains, rice and wheat can also be used as a proxy for agricultural production. These matters are left for further study.

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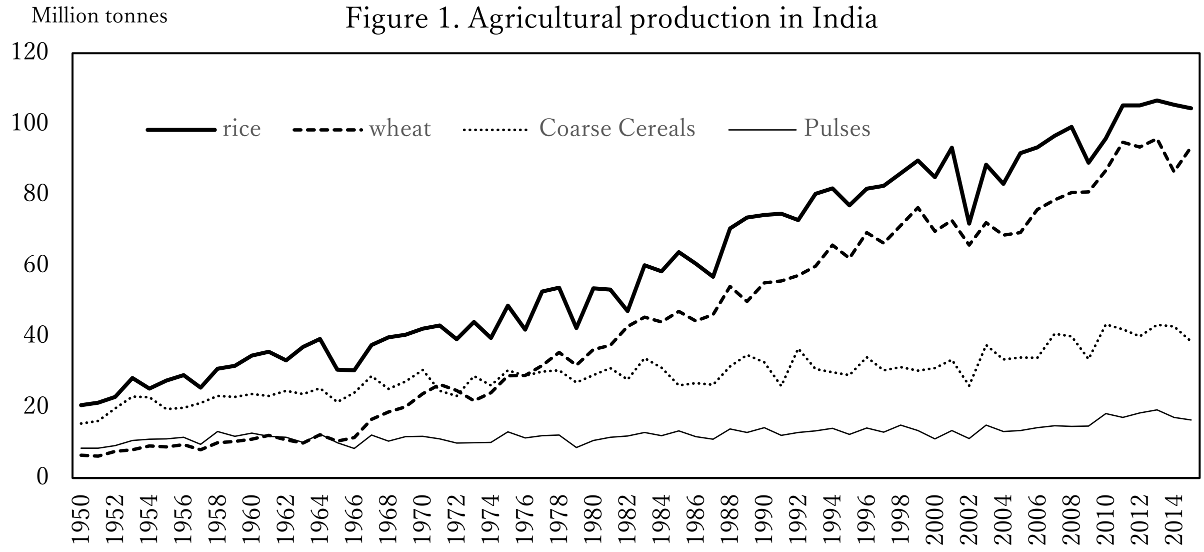
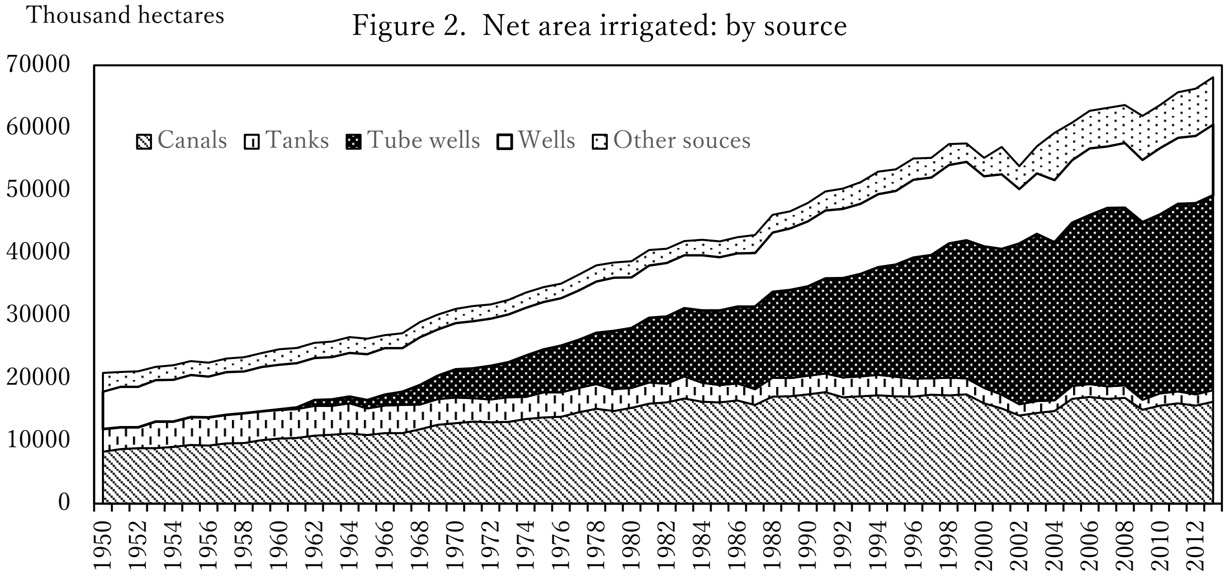
Figure 1. Agricultural production in India



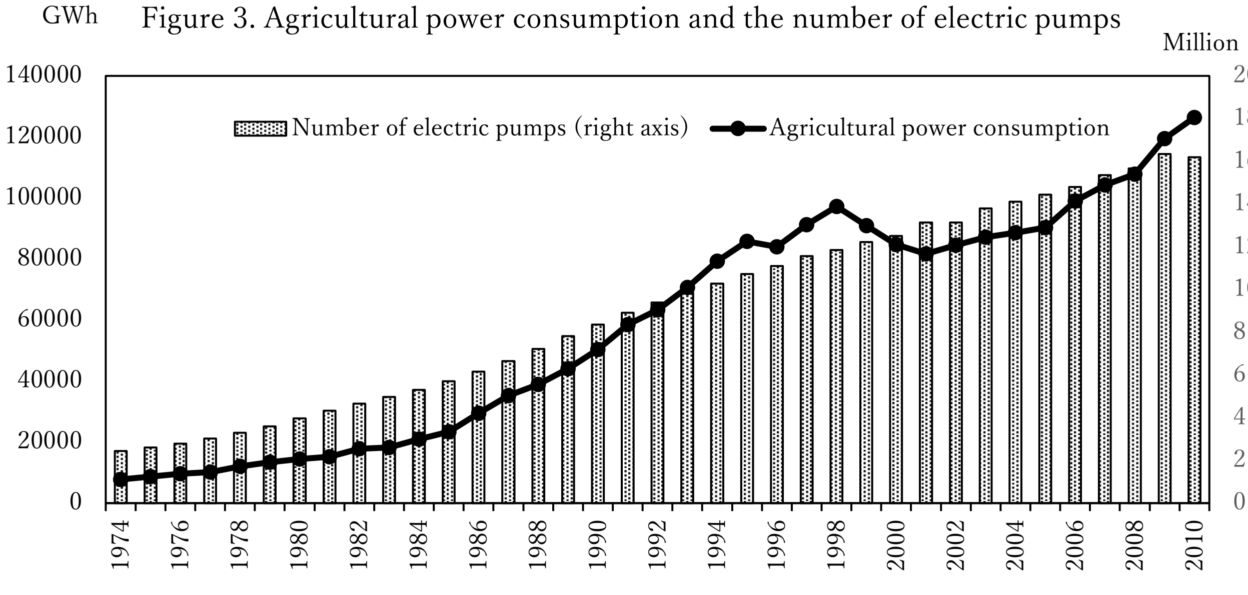
Source：EPWRF India Time Series, Ministry of Agriculture and Farmers Welfare (2017)

Figure 2. Net area irrigated: by source



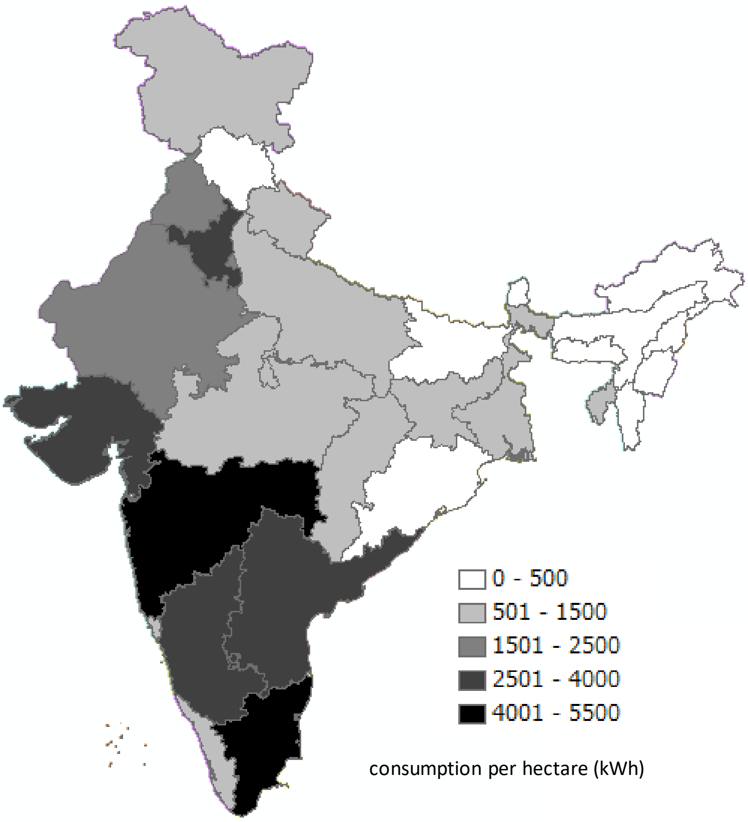
Source：EPWRF India Time Series

Figure 3. Agricultural power consumption and the number of electric pumps



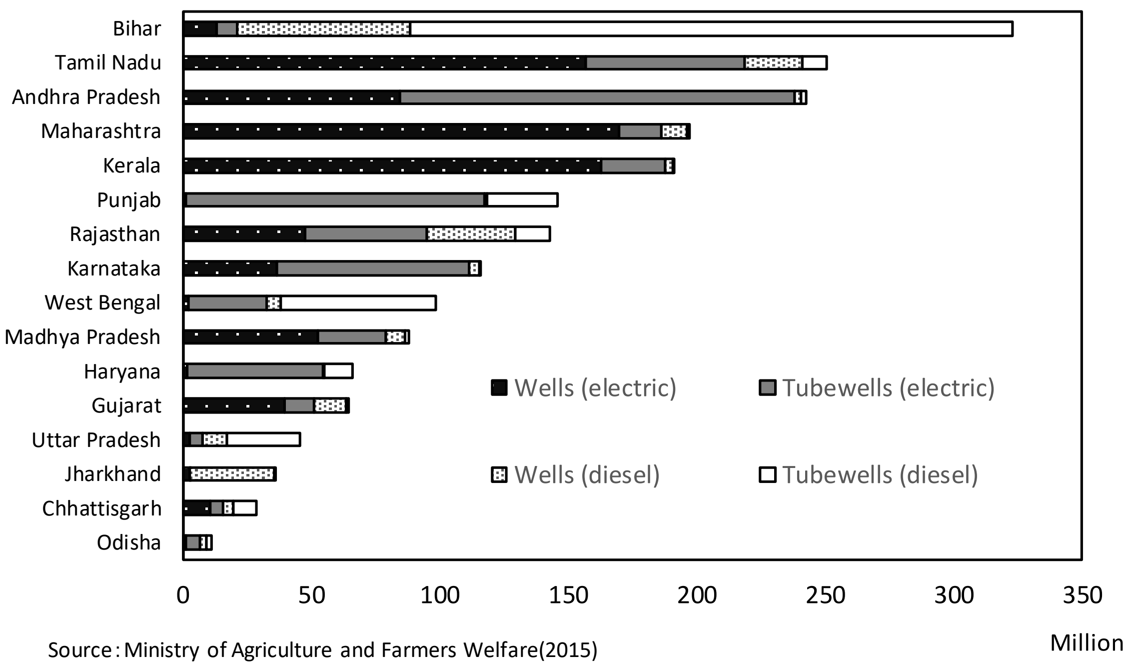
Source：EPWRF India Time Series

Figure 4. Agricultural power consumption by state（2010）



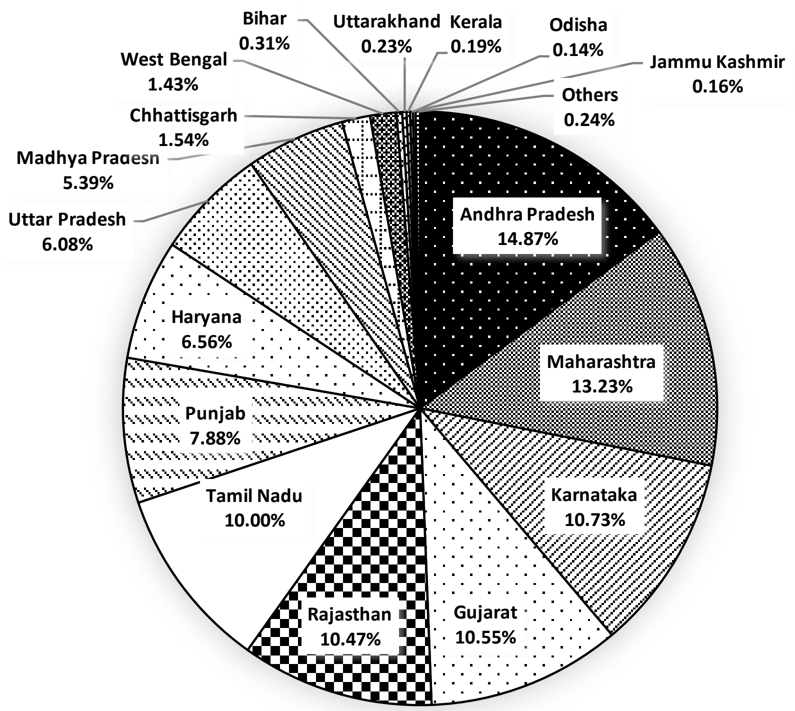
Source : EPWRF India Time Series, Ministry of Agriculture and Farmers Welfare (2015)

Figure 5. Number of irrigation pumps by state (2010)



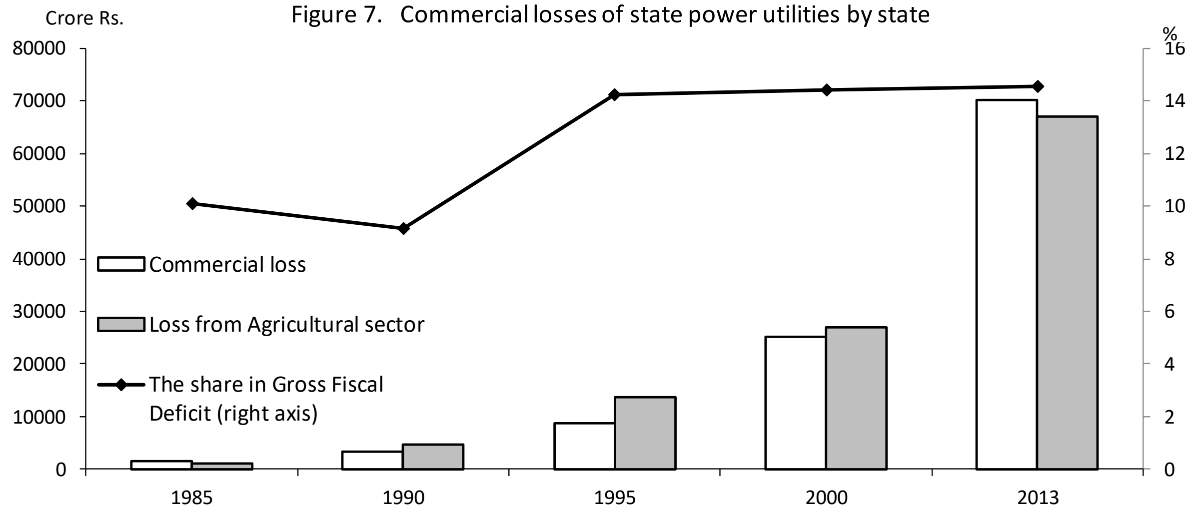
Source : Ministry of Agriculture and Farmers Welfare(2015)

Figure 6. Share of agricultural power consumption by state (2010)



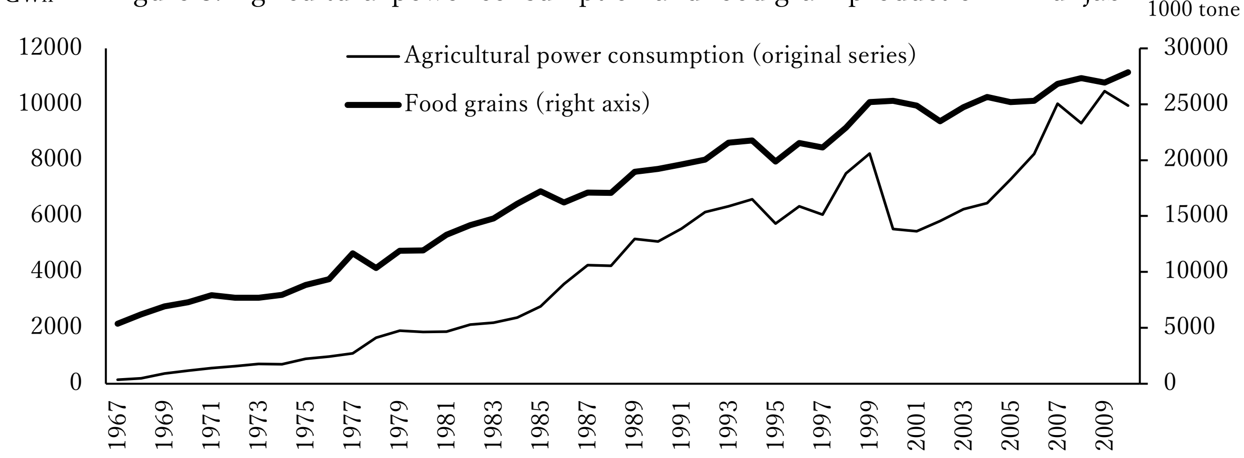
Source : EPWRF India Time Series

Figure 7. Commercial losses of state power utilities by state



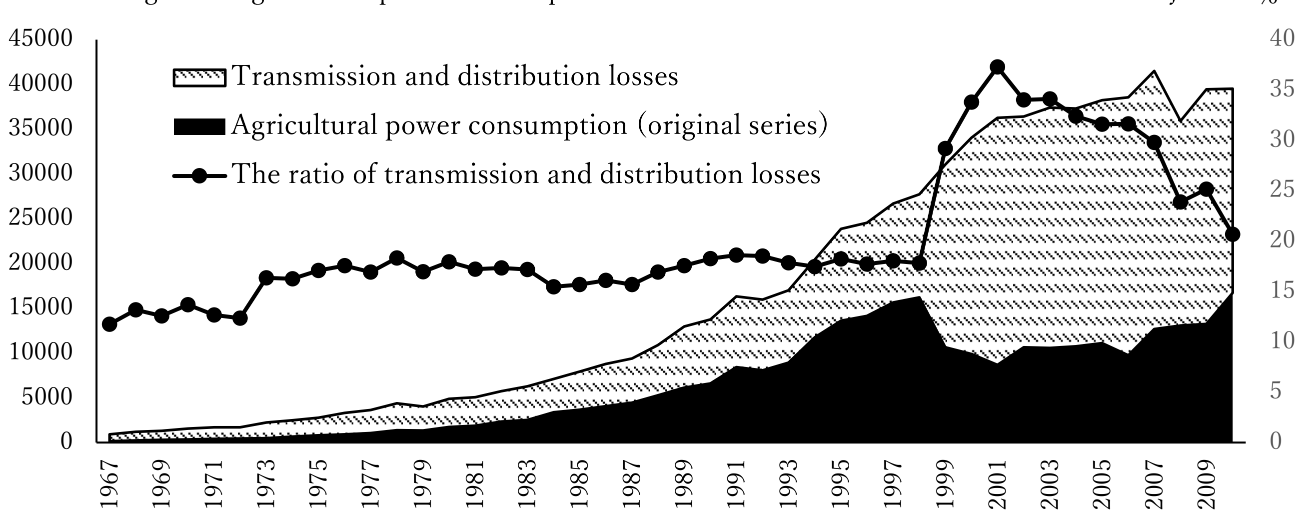
Source: Planning Commission (1992), (2002), (2013), Power Finance Corporation (2008)

Figure 8. Agricultural power consumption and food grain production in Punjab



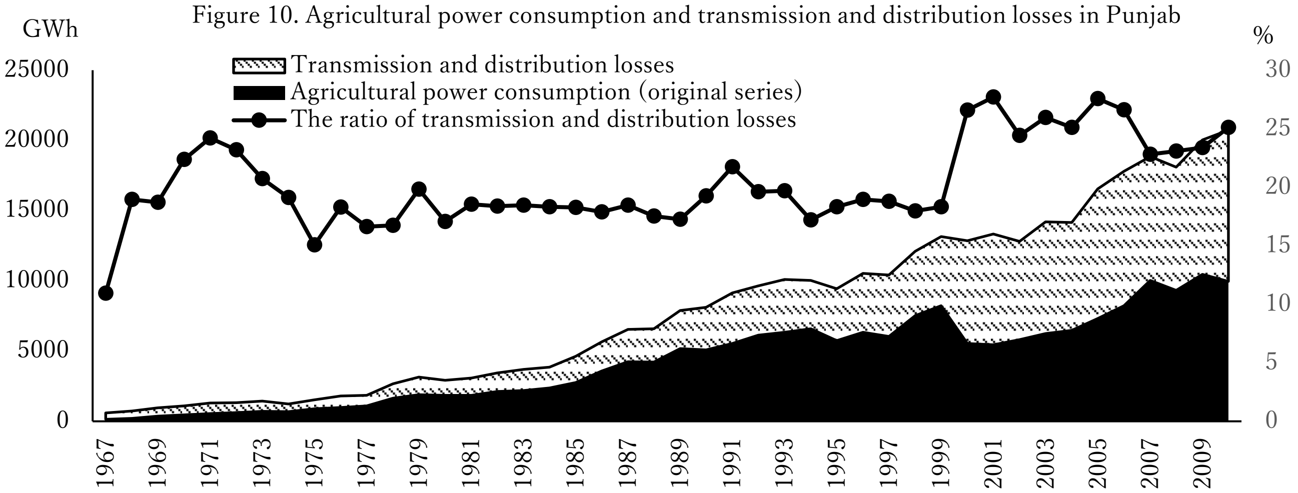
Source：EPWRF India Time Series

Figure 9. Agricultural power consumption and transmission and distribution losses in Punjab



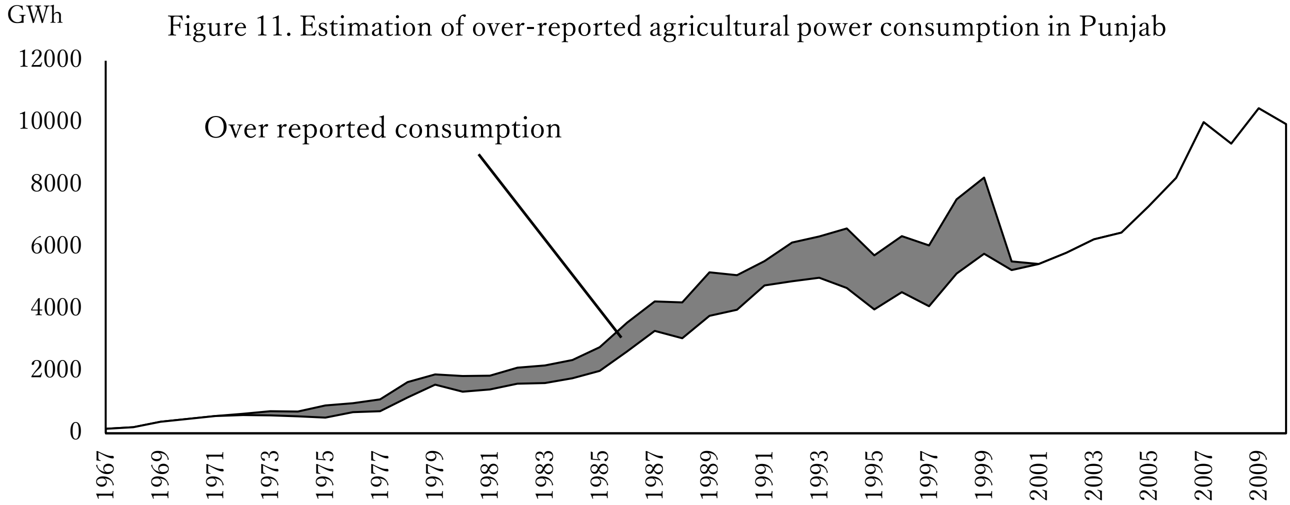
Source: EPWRF India Time Series

Figure 10. Agricultural power consumption and transmission and distribution losses in Punjab



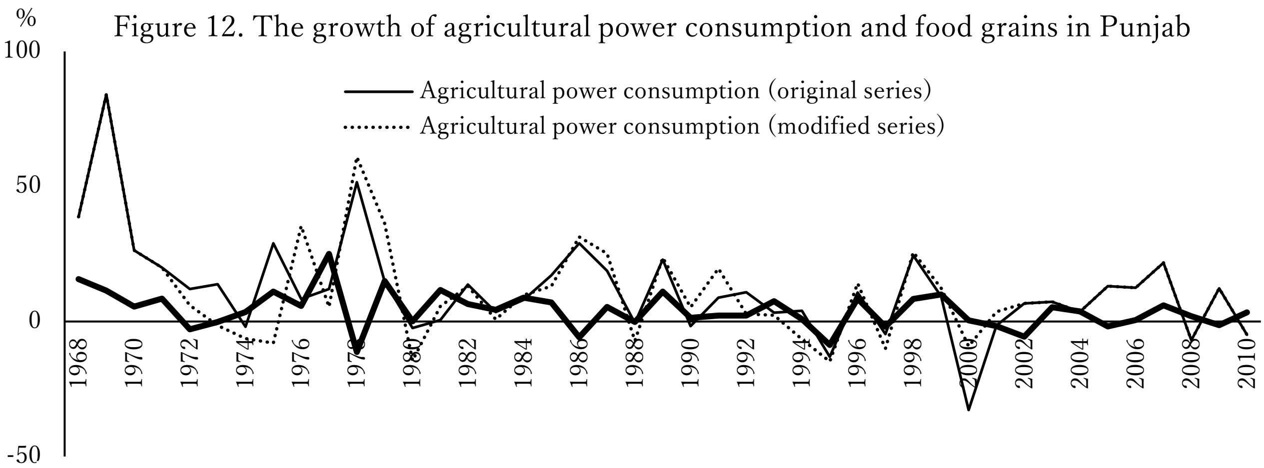
Source: EPWRF India Time Series

Figure 11. Estimation of over-reported agricultural power consumption in Punjab



Source ：Author's calculation using data from the EPWRF India Time Series

Figure 12. The growth of agricultural power consumption and food grains in Punjab



Source ：Author's calculation using data from the EPWRF India Time

Table 1. Unit root test results

	DF-GLS			ADF			Phillips-Perron		
	Statistic		Lag	Statistic		Lag	Statistic		Band width
Level									
Agricultural power consumption (original series)	-1.854		0	-3.327		0	-3.190		1
Agricultural power consumption (modified series)	-2.077		0	-2.875		0	-3.187		2
Food grains	-1.344		1	-1.662		1	-1.952		5
First difference									
ΔAgricultural power consumption (original series	0.884		8	-4.324	***	0	-5.015	***	1
ΔAgricultural power consumption (modified serie	-3.033	***	1	-4.470	***	0	-5.258	***	1
ΔFood grains	-2.445	**	1	-7.900	***	0	-8.426	***	3

'***' and '**' represent the rejection of the null hypothesis at 1% and 5% of significance. Test in levels are conducted by including a constant term and a time trend, whereas tests in the first differences includes a constant. The number of lags for DF-GLS and ADF test is determined by using the AIC criteria. A Newey-West bandwidth is used in Phillips-Perron test.

Table 2 Johansen cointegration test

Null Hypothesis	r=0		r=1
Original series			
Trace Statistic	24.53	***	2.92
Maximum-eigenvalue static	21.61	***	2.92
Modified series			
Trace Statistic	24.93	***	1.71
Maximu eigenvalue static	23.21	***	1.71

Lag length is 1. '***' and '**' represent the rejection of the null hypothesis at 1% and 5% of significance. Both the cointegrated vector and VAR include a constant.

Table 3 Granger causality

Null Hypothesis	Statistic	
ΔAgricultural power consumption (original series) ⇏ Δfood grains	0.202	
ΔFood grains ⇏ ΔAgricultural power consumption (original series)	2.166	
ΔAgricultural power consumption (modified series) ⇏ Δfood grains	1.695	
ΔFoodgrains ⇏ ΔAgricultural power consumption (modified series)	5.467	**

'***' and '**' represent the rejection of the null hypothesis at 1% and 5% of significance. Lag length is 1