Electricity consumption and economic growth in China: assessing Granger causality at provincial, electricity-market, and national levels

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Declaration

Except where appropriately acknowledged this thesis is my own work, has been expressed in my own words and has not previously been submitted for assessment.

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Abstract

The following thesis investigates the relationship between electricity consumption and economic growth in China over the period 1985-2012. Long and short run Granger causal relationships between these variables are ascertained by applying a vector error correction model to national, electricity-market, and provincial-level data. A comparison is then made between the relationships obtained from these different datasets. The results suggest that a large amount of information is lost as a result of aggregation, with data at the national and electricity-market levels being unable to accurately reflect prevailing relationships observed at the provincial level. This observation is particularly relevant given the predominance of national level studies found in the literature.

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1 Introduction

Over the past 40 years China has experienced rapid economic growth, as well as an exponential increase in electricity consumption. This observation has led a number of academics to analyse the role that electricity, an important intermediate good, plays in the context of economic development. An important question which a number of studies have attempted to answer relates to the causal relationship between these two variables. Specifically, does an increase in electricity consumption cause economic growth, or is increased electricity consumption merely a consequence of a growing economy? An understanding of the causal relationship between these two variables can have significant implications for the design of electricity networks and markets, as well as the planning of electricity infrastructure. The current study investigates the causal relationships between these two variables by using Chinese datasets with differing levels of aggregation. In doing so it also enables a comparison to be made between the results obtained from these different datasets - giving an indication of the ability of highly aggregated data to reflect prevailing trends at regional and provincial levels.

Questions relating to the causal relationship between variables are typically answered through the paradigm of Granger causality. This modelling framework assesses whether past values in one series can be used to predict future values in another. One tool often used to carry out an analysis of Granger causal relationships is the vector error correction model (VECM). This model has the ability to analyse both short and long run causal relationships between variables - leading a number of studies to adopt this approach when analysing the relationship between electricity consumption and economic growth (Payne, 2010*a*,*b*). Such analyses have often yielded contentious results, often contradicting the findings made in previous studies. For example, Shiu & Lam (2004) found evidence for uni-directional Granger causality running from electricity consumption to real gross domestic product (GDP) - precisely the opposite result found by Boqiang (2003). These different conclusions are despite the fact that both studies used similar methodologies and investigated similar time periods - 1971-2000 for Shiu & Lam (2004) and 1978-2001 for Boqiang (2003). Typically such discrepancies are attributed to the way in which model parameters are specified, as well as a model's sensitivity to the time period under investigation. A question which has received little attention in the literature is the extent to which aggregation can drive these contradictory findings.

It may not be the case that Granger causal relationships observed at the national level are consistent with those observed at the electricity-market and provincial levels. For example, if it is observed that the long run Granger causal relationship runs from electricity consumption to economic growth in two provinces, it may not be the case that the same relationship will be observed when these two series are aggregated and the tests repeated. The current thesis addresses this gap in the literature by analysing the impact that aggregation can have on the conclusions drawn with respect to Granger causality tests. In doing so the thesis explores the ability of aggregate data to convey the prevailing causal relationship between electricity consumption and economic growth at regional and provincial levels.

An initial exploratory analysis of electricity consumption and economic growth data for China further motivates the current study. In Figure 1 the percentage growth rates in electricity consumption and real gross domestic product (RGDP) at the national level between 1985 and 2012 are shown. The two series appear to move together. However the relationship at the provincial level is less clear: while some provinces, such as Guangxi in Figure 2, appear to show strong co-movements between series others, such

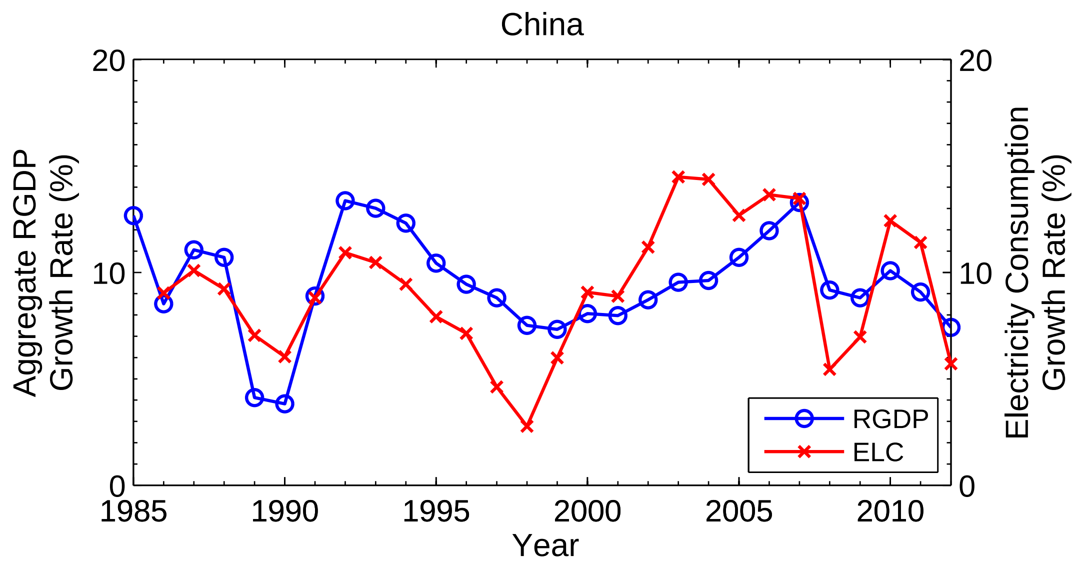

Figure 1: China - Electricity consumption and real GDP growth rates

as Xinjiang in Figure 3, do not.

Such regional heterogeneity observed in China begs two questions: how useful are aggregate data when attempting to determine causal relationships at the national level, and how robust are these relationships to changes in the sample period under investigation? The current thesis attempts to systematically answer these questions by applying the VECM model to datasets with differing levels of aggregation, and then compares the results.

A custom built dataset for China has been constructed - spanning a longer period than any other comparable study for the country. The majority of previous studies use national level data when analysing the relationship between electricity consumption and GDP, with only a small number of studies utilising provincial-level data. However, the time periods under consideration in these disaggregated studies are short - typically from 1995 onwards (Wang et al., 2011). This is likely due to the fact that the National Bureau of Statistics (NBS) of China only reports provincial level electricity

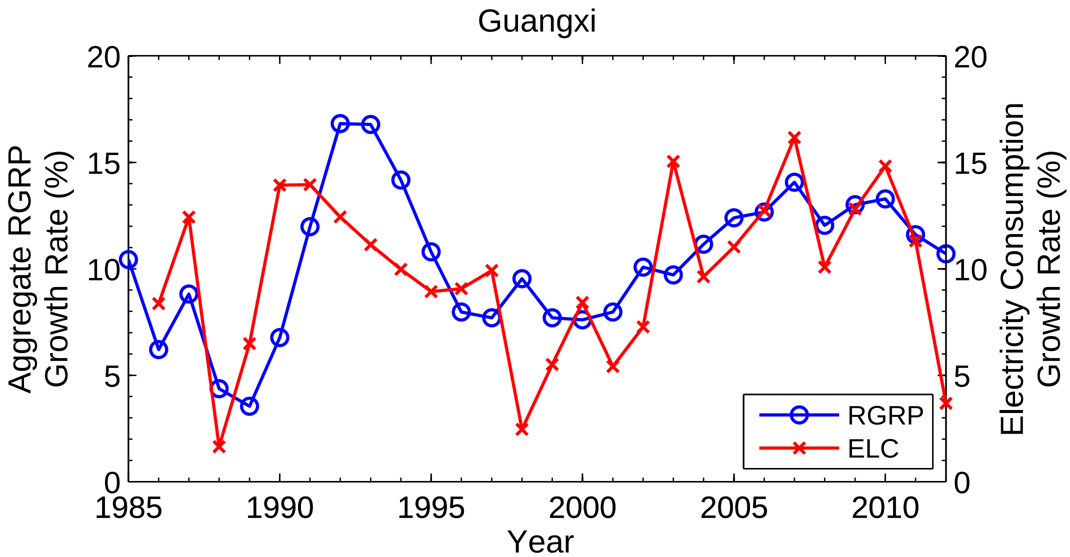

Figure 2: Guangxi - Electricity consumption and real GRP growth rates

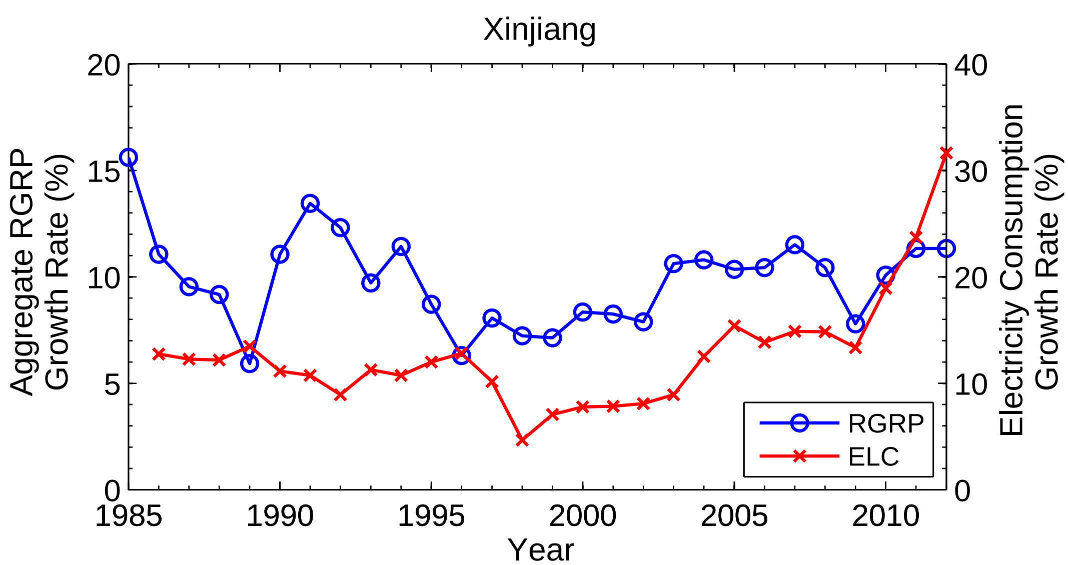

Figure 3: Xinjiang - Electricity consumption and real GRP growth rates

consumption data from 1995 (NBS, 2015). To construct a longer series one must look to individual provincial statistical yearbooks - a step taken in the current analysis. Over 100 provincial yearbooks were examined, with the data integrated with that found on the NBS database. This has enabled a series from 1985-2012 to be constructed for almost all provinces within China.

The use of well accepted econometric techniques, in conjunction with an up-to-date database, allows the current study to make an important and relevant contribution to a number of policy debates currently under way in China. Most notably, the results of this study can assist policy makers in better understanding the potential economic implications of the establishment of a nationwide emissions trading scheme. Recent announcements by the Central Government suggest that a cap-and-trade scheme will be implemented by 2017 (Wen, 2015). As approximately 68% of electricity in China is produced using coal, an emissions-intensive fuel, an understanding of the causal relationship between electricity consumption and growth can assist in modelling the impacts of such a policy (Liu, 2015). For example, if there is a uni or bi-directional causal relationship from electricity consumption to GDP, it implies that policies that reduce electricity consumption will have a detrimental effect on economic growth. Conversely, if uni-directional causality runs from GDP to electricity consumption, or if there is no causal relationship, then energy conserving policies are unlikely to have a significant impact on GDP (Payne, 2010*a*). Therefore, an analysis of the causal relationship between these two variables not only can be used to assist in planning electricity infrastructure, but can also be used in more complex models which attempt to forecast future electricity demand, as well as assist in the policy evaluation of different types of emissions abatement schemes.

The following sections of the thesis are arranged as follows. Chapter 2 provides an overview of the historical development of China's electric power industry, and of the attempts made to analyse the causal relationship between electricity consumption and GDP. Chapter 3 discusses the data used, while Chapter 4 details the methodology adopted in this study. Econometric results are presented in Chapter 5, followed by concluding remarks in Chapter 6.

2 Literature review

The following literature review provides a brief background to the major developments that have occurred over the past 60 years in China's electric power industry. An overview of the econometric methods commonly used to investigate the causal relationship between electricity consumption and GDP also is presented - focusing on several studies that have analysed China specifically.

2.1 China's electric power industry

Over the past 60 years the electric power industry in China has undergone several distinct phases of development. The first major phase occurred from 1949 following the Communist Party's rise to power. At this time electricity assets were nationalised and a policy of 'unification' was adopted - government policies were aligned with the operating decisions of state owned enterprises (Xu & Chen, 2006). The prioritization of the industry's development by the Central Government saw it grow rapidly. However, a lack distinction between the roles of Government and business, as well as restrictive investment policies, disincentivised the participation of private firms within the sector (Ma & Oxley, 2012; Zhang & Heller, 2003). The resulting lack of investment led to significant power shortages within China, motivating the implementation of a number of industry reforms.

As a result of widespread power shortages, the Central Government enacted laws in 1985 to actively encourage investment in the electric power industry, with efforts also made to separate the responsibilities of business and government (Xu & Chen, 2006). These reforms delegated a number of responsibilities to provincial governments in relation to the operation of electric power utilities and assets - helping to decentralise the decision making and planning processes within the industry (Xu & Chen, 2006). While these reforms did increase capacity, a number of problems still persisted. One consequence of the reforms was the proliferation of small but relatively inefficient thermal-coal power stations. The ease with which smaller firms could be approved, in conjunction with their lower capital requirements, made them attractive investments for provincial governments and foreign investors (Zhang et al., 2001). Additionally, inter-provincial political barriers hampered the development of electricity transmission across provinces. These persistent problems motivated the Central Government to pursue more than just regulatory reform - leading to the fundamental restructuring of the industry in 1997 through the establishment of the State Power Corporation (SPC) (Xu & Chen, 2006).

The establishment of SPC in 1997 created a clearer distinction between the roles of government and businesses. SPC operated autonomously, and was regulated by the State Trade and Economic Commission (STEC), as well as the State Development and Planning Commission (SDPC) (Xu & Chen, 2006). Throughout most of China SPC operated as a vertically integrated monopoly - controlling a majority of generation, transmission, and distribution assets. In an attempt to further increase the efficiency with which resources were allocated, pilot schemes aimed at increasing competition between generators were established in Zhejiang, Shandong, Jilin, Liaoning, Heilongjiang, and Shanghai (Xu & Chen, 2006). These schemes attempted to separate the roles of power generators and transmission network operators with generators now competing to sell their electricity to the grid (Ngan, 2010). The success of these pilot schemes ultimately led to the dismantling of SPC in 2002, separating the roles of generation and transmission assets within China. Two grid operators, State Grid and China Southern Grid, managed the transmission assets, while five electricity generation businesses were allocated a majority of the country's generation utilities (Ngan, 2010).

The restructuring of generation and transmission assets, as a result of the dismantling of SPC, has increased competition among GenCos within China (Ngan, 2010). However, several serious problems still hamper the industry's development. Despite structural reform to increase autonomy of individual firms, the influence government has on the industry is still clearly observable in a number of regions. The setting of electricity prices is one such example. It is not uncommon for GenCos to be paid according to complex arrangements that may factor in their costs of production and dates of generation (Yeoh & Rajaraman, 2004). These complex pricing arrangements are vestiges of previous reforms that incentivised investment by guaranteeing profits (Ma & Oxley, 2012). In an effort to deal with these problems, another wave of experimentation has been pursued - the liberalisation of wholesale electricity markets.

The liberalisation of electricity prices within wholesale markets allows the costs of production to be better reflected in the price of electricity, increasing the efficiency with which resources are allocated within the industry. Such markets have been trialled in Shenzhen and Inner Mongolia, with similar pilot schemes to be established in Anhui, Hubei, Ningxia, and Yunnan. These schemes aim to simplify the tariff structures currently in place in these markets (Aizhu, 2015; NDRC, 2007). Additionally, State Grid is pursuing the development of ultra high voltage (UHV) transmission lines across the country, with the intention of establishing a unified electricity market (Kemp, 2014).

It is evident from the literature that China's electric power industry has undergone significant structural transformation. It is also clear that many of these structural reforms were (and continue to be) implemented in selected provinces before being disseminated nationally. As these reforms influence the way in which electricity is produced and consumed within a province, there is likely to be significant cross-regional heterogeneity with respect to the relationship between electricity consumption and GDP. Therefore, information may be lost when provincial level data are aggregated to form national statistics - potentially leading to spurious results if national level data are used when analysing the causal relationship between these variables.

2.2 Electricity consumption and GDP

Kraft & Kraft (1978) were the first to analyse the causal relationship between energy consumption and gross national product (GNP), with their seminal paper motivating numerous studies in this area. Econometric methods developed by Engle & Granger (1987) helped to formalise the way in which to conduct such analyses, with the tools developed still commonly found in the literature today (Ozturk, 2010; Payne, 2010*b*). Methods such as vector auto regressions (VARs) and vector error correction models (VECMs) are commonly adopted, allowing Granger causal relationships between variables to be determined. The ability of VECMs to analyse long and short run causal relationships has seen them grow in popularity, with a number of recent studies utilising this technique to investigate the causal relationship between electricity consumption and GDP (Payne, 2010*a*). A number of studies have also used these models with panel data, allowing cross-country analyses to be conducted (Mahadevan & Asafu-Adjaye, 2007; Yoo, 2006; Lee & Chang, 2008). While a large number of countries have been analysed using these methods there is a clear subset of the literature devoted to the analysis of China.

Shiu & Lam (2004) were among the first to analyse the causal relationship between GDP and electricity consumption in China. Their analysis applied a VECM model to national level electricity consumption and GDP data for the period 1971-2000. Their findings suggest that uni-directional Granger causality runs from electricity consumption to economic growth in the short and long run. However, these conclusions conflict with those drawn by Chen et al. (2007) who conducted a similar analysis for ten ASEAN countries over a similar time period, 1971-2001, finding no evidence of Granger causality between the two variables. The results of these studies also conflict with the conclusions drawn by Boqiang (2003), who investigated the relationship between electricity consumption and GDP for the period 1978-2001 - finding uni-directional Granger causality running from GDP to electricity consumption. These conflicting findings are often attributed to the sensitivity associated with the specification of model parameters and the time period under investigation (Payne, 2010*a*,*b*). An important observation when surveying the literature is the predominance of studies using national level GDP and electricity (or energy) consumption data.

Of all the papers surveyed in this literature review relating to China, only three utilised disaggregated data. Wang et al. (2011) used provincial level data to investigate the relationship between energy consumption, CO_2 emissions, and economic growth using a panel data model for the period 1995-2007. They found bi-directional causality between energy consumption and GDP, also finding energy consumption and GDP to be the long run causes of CO_2 emissions. Another panel data analysis by Chuanguo Zhang (2012) used a VECM to investigate the relationship between energy consumption and GDP at both the regional and sectoral levels in China for the period 1995-2008. In their analysis they divided China into five regions: north, east, west, south, and central - observing regional variation in the causal relationships between energy consumption and GDP. The longest provincial level time series found in the literature was used by Fei et al. (2011) who investigated the relationship between energy consumption, CO_2 emissions, and GDP for the period 1985-2007. In their analysis China was also divided into regions, east and west, again finding regional variation in the long run relationship between GDP and energy consumption.

In summary, this review of the literature reveals a lack of consensus among analysts regarding the direction of Granger causality between electricity consumption and GDP in China. The few studies that have been conducted using disaggregated data suggest that the causal relationship between energy consumption and GDP is subject to regional variation. However, to date no study has conducted a completely disaggregated analysis - analysing the relationship between electricity consumption and gross regional product (GRP) for each province independently. Furthermore, no study has analysed how the results found at the provincial level compare to those found when analysing regional blocks, as well as national level data. Therefore, there exists an opportunity to fill a gap in the literature by conducting a disaggregated analysis, comparing these results with those obtained when analysing regional blocks, as well as national level data. Doing so would allow a better understanding of the regional variation that exists between these variables. A comparison of the results obtained at the different levels of aggregation also would help to identify possible limitations associated with the use of national level data when conducting such an analysis. Given that a majority of studies in the literature use national level data, the results of this phase of the analysis could have a significant impact on the way in which future research is conducted in this field.

3 Data

Yearly electricity consumption, GDP, and provincial level GRP data were collected from the National Bureau of Statistics (NBS) of China. The comprehensive nature of the NBS' online database made it the preferred resource when collecting data for the current analysis. However, this data source did have limitations with respect to the length of the time-series available, as well as missing observations within a number of series. In order to address these problems, provincial statistical yearbooks were examined. That helped fill a number of missing observations and extended the length of the time series significantly. Numerical methods were used to interpolate values that could not be found in the provincial yearbooks. These methods are outlined in the following section, along with a discussion of the methodology used to facilitate the sensible collation of data from multiple sources.

3.1 Properties

The NBS report nominal value-added GDP at the national level, and GRP at the provincial level yearly. The NBS also reports GDP and GRP indices which measure the real economic growth rate at constant prices. The base-year used to calculate these growth rates at constant prices has changed a number of times since the NBS began reporting GDP and GRP data, with the most recent being 2005 (NBS, 2015). It should be noted that the NBS retrospectively adjusts GDP and GRP data when a new base-year is adopted. Therefore, if one wishes to conduct an analysis using data from 2005 onwards, and data must be collated from multiple sources, it is only sensible to refer to yearbooks that have been published after 2005. Comprehensive electricity consumption data are also reported by the NBS at the national and provincial levels, with these data representing the total amount of electricity consumed by residential and industrial processes in a given year (NBS, 2015).

3.2 Sources

The NBS online database contains comprehensive provincial level data from 1995 onwards, making it the preferred resource when conducting the current analysis. In order to extend the length of the series under investigation, provincial statistical yearbooks were consulted. The list of resources used is reported in Appendix A. The collation of data from these various sources allowed an additional ten years of GRP data to be collected, enabling the current study to analyse the period 1985-2012. A similar procedure was performed for electricity consumption data, with the NBS website and Chinese Energy Statistical Yearbooks (CESY) used to construct series spanning the period 1985-2012. However, there were limitations to these resources, with electricity consumption data missing for most provinces between 1991-1994. The years in which data were missing coincide with a period of significant re-structuring in China's electric power industry - a potential explanation for their absence. Provincial yearbooks were consulted to find data for these years, with these resources helping to minimise the number of missing observations.

3.3 Collation

A number of potential problems can arise when collating data from different sources. This is especially true for China where the accounting procedures for GRP vary between provinces. In order to address this issue, a consistent and methodological procedure was developed to sensibly collate data from a number of different sources. The first stage in collating information involved consultation of the NBS' website, as it contained comprehensive provincial level data from 1995-2012. When seeking to incorporate data from provincial yearbooks, series that would partially overlap this time-frame were sought. For instance, Beijing's Statistical Yearbook 2010 contains data from 1979-2009. The overlap of these two time periods (the years 1995-2009) enabled an important cross-check to be made. If the data in the overlapping series differed significantly (greater than 1%) then the two series are likely to have been constructed with different accounting methods, and they should not be collated. For a majority of provinces the data matched exactly - allowing the length of a number of series to be extended significantly. A similar cross-checking procedure was conducted when collating electricity consumption data from multiple resources. While this procedure worked for approximately half of the provinces, a number of gaps still remained. Numerical methods were employed to address this issue, as outlined below.

3.4 Data processing

3.4.1 Numerical methods

Numerical methods were used to interpolate values for the years in which electricity consumption data were unavailable. Cubic splines were selected as an appropriate

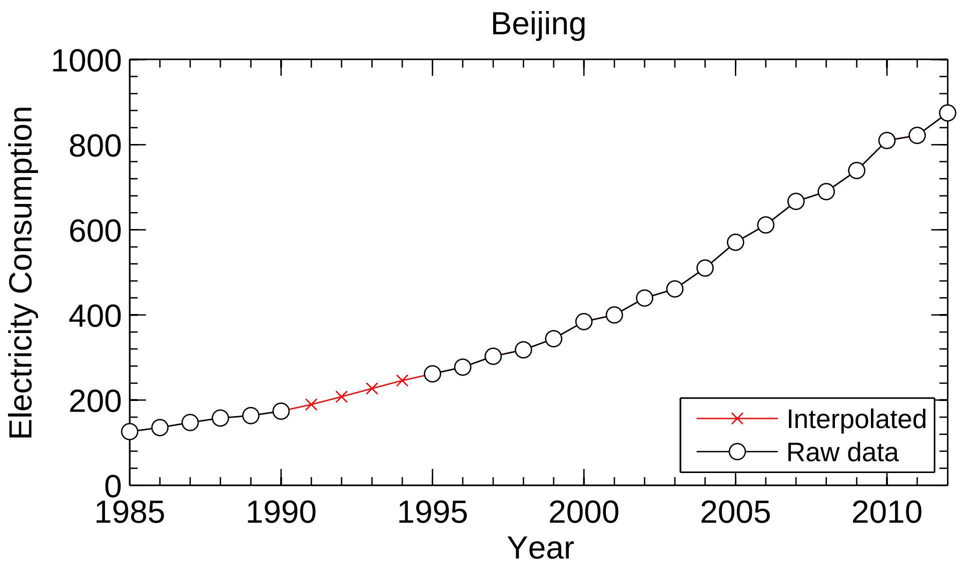

Figure 4: Beijing - Interpolation example

method, given their ability to preserve non-linear trends when interpolating missing values (Fung, 2006). This method was implemented by using known values either side of the missing data to fit a cubic function. The cubic was then evaluated at the desired years, thereby interpolating the missing values. Figure 4 illustrates the results of this interpolation technique for Beijing.

Dots represent the known data points while the red crosses denote the interpolated values. For this thesis a five year window either side of the missing values was taken. From Figure 4 the interpolated data fit the known values reasonably well. Also, the fact that the missing values are at the beginning of the time series, where the growth in electricity consumption is relatively slow and constant, is beneficial in the sense that the cubic splines are less likely to miss large variations in this series.

3.4.2 Real GDP/GRP calculation

When conducting an analysis with GDP and GRP data it was necessary to separate price effects from changes in real output. From the data reported by the NBS there are two methods which can used to convert these data into real-terms. The first method involved identifying the nominal GDP/GRP in 2005, as this was also the real value - 2005 was the base-year at which prices were held constant. Series in real terms were then calculated by taking the respective GDP/GRP indices (which represent real growth rates at 2005 constant prices) and compounding the known real GDP/GRP value in 2005 backwards and forwards in time.

The second method involved constructing a series of GDP/GRP deflators. This was accomplished by calculating the nominal GRP growth rate for all years in the sample, and then subtracting the real growth rate (found from the GDP/GRP indices) from this value as shown in Equation (1). This measure of inflation was then converted into a fixed-base index, enabling nominal values to be converted into real-terms.

$$\text{inflation} = \text{nominal growth rate - real growth rate} \tag{1}$$

The two calculation methods yield very similar results, with a comparison shown in Figure 5. The blue crosses show real GRP (RGRP) calculated with the first method, while the red circles represent the data constructed when using the second method (RGRP2). It should also be noted that the RGRP calculated with these methods are generally consistent with the data used by Shiu & Lam (2004) in a similar analysis.

While the two methods yield similar results, the second method is preferred because real

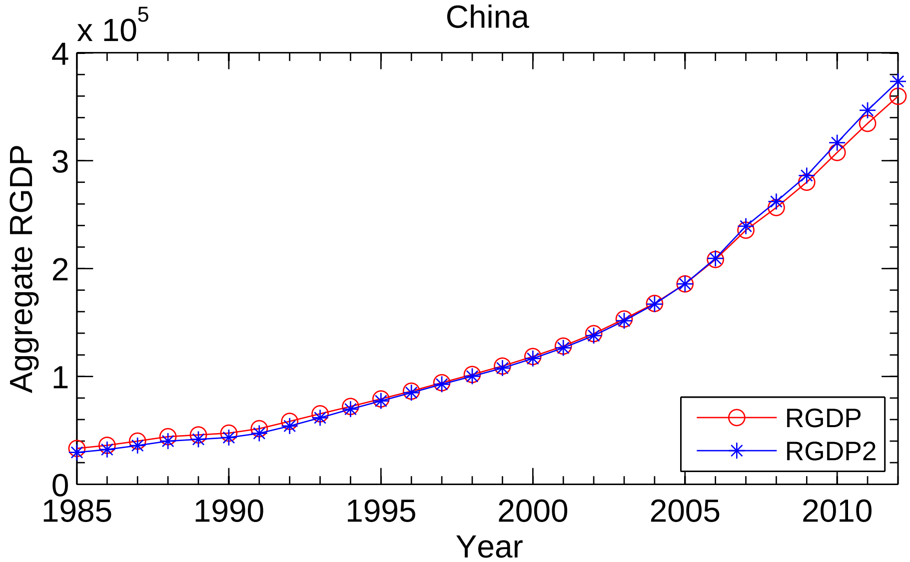

Figure 5: Comparison between RGDP calculation methods

growth rates are only reported to one decimal place. Compounding these growth rates forwards and backwards in time also compounds the measurement error associated with these values. Constructing a GDP/GRP deflator for each year and then converting it into a fixed-base index minimises the extent to which measurement error is compounded. For this reason the second RGRP calculation method is used in the following analysis.

3.4.3 Exclusions and aggregation

Over the time period under investigation, some Chinese provinces have been re-configured. The most significant example is the separation of Chongqing and Sichuan. Chongqing, formerly a municipality of Sichuan, was elevated to the status of provincial level municipality 1997. Consequently, yearbooks after this date treat Chongqing as being independent of Sichuan. As the sample period overlaps with this transition date, the current study adopted the approach used by Chuanguo Zhang (2012) and aggregated the two provinces - effectively treating Sichuan and Chongqing as being part of the

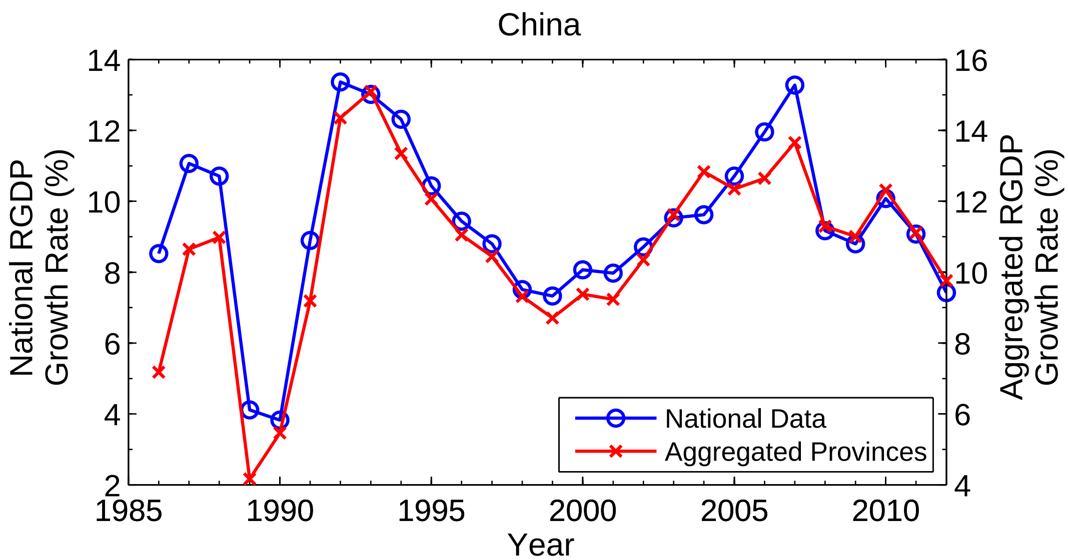

Figure 6: Difference between aggregated and national level data

same provincial unit.

Despite efforts to collate data from multiple sources, insufficient electricity consumption data were available for Hainan and Tibet. They are therefore excluded from the current study. These provinces are relatively small and underdeveloped, so their absence when conducting regional analyses is unlikely to have an appreciable effect on the results obtained. Therefore, while there exist 31 provincial units in China, two have been excluded, and one has been re-combined with another province - leaving 28 provinces on which to conduct the following analysis.

It should also be noted that there are limitations when aggregating provincial level data. The NBS states that provinces may differ slightly in their accounting of GRP and other statistics (NBS, 2015). Therefore, the sum of GRP data collected for all provinces in a particular year may not exactly equal the GDP reported for China as whole. Figure 6 illustrates the magnitude of this difference.

The data in Figure 6 shows that while aggregation leads to level discrepancies, the general trends and cycles observed in manually aggregated data are close to those when using national level data. Therefore, when aggregating provincial level data into regional blocks the growth rates obtained are likely to be a reasonable approximation of the true GRP growth rate within that region.

4 Methodology

The statistical analysis of causal relationships between variables was first proposed by Granger (1969). In this paper Granger asserts that causal relationships, in a statistical sense, could be identified by assessing the ability of lagged values in one series to predict future values in another. There are, however, limitations associated with this framework, with Granger & Newbold (1974) finding that Granger causality tests on non-stationary series could lead to spurious results. The theoretical foundations for this observation were made by Phillips (1986) and Hamilton (1994). One remedy to this problem involves differencing any non-stationary series until it becomes stationary. The number of times a series must be differenced for it to become stationary is known as the order of integration. For example, a series is said to be integrable of order d, or $I(d)$, if it must be differenced d times before it becomes stationary, or $I(0)$.

Error correction models (ECMs) were popularised by Engle & Granger (1987) and provide a framework in which to test long and short run causal relationships between variables. A key advantage to these error correction models is their ability to identify both long and short run causal relationships between series. These desirable features have seen them applied extensively in the literature, and have become particularly common when analysing the relationship between electricity consumption and GDP (Payne, 2010*a*) - motivating the decision to utilise a vector error correction model in the current study.

Panel data models have been applied previously to ascertain the relationship between electricity consumption and GDP in China (Wang et al., 2011; Chuanguo Zhang, 2012; Fei et al., 2011). However, there are limitations associated with the use of fixed and random-effects models in the context of the current analysis. Fixed-effects models assume that the unobserved heterogeneity between provinces is time invariant. This assumption is unreasonable given the fundamental transitions that have occurred in China's electric power industry over the last 50 years. As there exists no well-accepted set of variables to control for this time varying heterogeneity, a fixed-effects model was deemed inappropriate for the current analysis. Similarly, the use of a random-effects model was also precluded. This model assumes that the unobserved time varying heterogeneity is uncorrelated with electricity consumption. This assumption is almost certainly unreasonable, as the structure of a province's electric power industry is likely to have some influence on the amount of electricity consumed. For these reasons this thesis has not used a panel data model, and has instead conducted a completely disaggregated analysis - analysing the direction of Granger causality for each province independently. The manual aggregation of provinces when conducting a regional analysis then allowed questions relating to the effect of aggregation to be answered. Conducting the analysis in this way allowed a better understanding of the regional variation of the Granger causal relationship to be formed, as well as an analysis of the effects of aggregation to be undertaken.

4.1 Model specification

A vector error correction model (VECM) is a general framework in which to analyse the Granger causal relationship between two or more time series. The model attempts to capture short run causal relationships through the use of lagged variables, as well as long run relationships through the use of error-correction terms. The model specification as set-out by Shiu & Lam (2004) is used for the current analysis and is shown below:

$$\ln RGRP_t = \beta_0 + \beta_1 \ln ELC_t + \mu_t \tag{2}$$

$$\Delta ELC_t = \alpha_1 + \alpha_x \mu_{t-1} + \sum_{i=1}^{n} \alpha_{11}(i) \Delta RGRP_{t-i} + \sum_{i=1}^{n} \alpha_{12}(i) \Delta ELC_{t-i} + \epsilon_{xt} \tag{3}$$

$$\Delta RGRP_t = \alpha_2 + \alpha_y \mu_{t-1} + \sum_{i=1}^{n} \alpha_{21}(i) \Delta RGRP_{t-i} + \sum_{i=1}^{n} \alpha_{22}(i) \Delta ELC_{t-i} + \epsilon_{yt} \tag{4}$$

In Equations (2) to (4) $RGRP$ and ELC represent real gross regional product and electricity consumption respectively, with ΔELC and $\Delta RGRP$ denoting the logged first-difference of these variables. Logs are taken in Equation (2) to remove non-linear trends, as well enabling the first-difference of these variables to be interpreted as approximate percentage changes. The first step in analysing the Granger causal relationships between these variables involved running the regression specified in Equation (2) using ordinary least squares (OLS). The estimated residuals, $\hat{\mu}_t$, were used to construct the error correction term (ECT). Long run causal relationships can be identified by analysing the significance of the lagged ECT, μ_{t-1}, which represents the deviation from the long run relationship between electricity consumption and RGDP/RGRP in the preceding period. By using this term in equations (3) and (4) it is possible to establish which variable is moving to restore the long run equilibrium. For example, if α_x were significant in Equation (3) then it suggests that electricity consumption is the variable which restores the long run equilibrium relationship between these variables. Therefore if RGRP were to increase in period t, resulting in a long run disequilibrium, electricity consumption would increase in period $t+1$ to restore equilibrium, hence Granger causality running from RGRP to electricity consumption. The converse would be true if α_y were significant. If both α_x and α_y are found to be significant then bi-directional Granger causality is said to occur - both variables interact to restore the long run equilibrium.

Short run Granger causal relationships were identified by analysing the joint significance of the lagged variables in Equations (3) and (4). For example, if the lagged RGRP variables in Equation (3) were found to be jointly significant then information contained in the RGRP series assisted in predicting future electricity consumption values. Considering this same scenario, if lagged electricity consumption values were found to be jointly insignificant in Equation (4) then past electricity consumption values do not assist in explaining future RGRP values. In this situation short run Granger causality would be uni-directional, running from RGRP to electricity consumption - past RGRP values help explain future electricity consumption values but not vice versa. If both lagged RGRP and electricity consumption variables were found to be significant in Equations (3) and (4) respectively, then short run bi-directional Granger causality would be said to exist between these variables. Therefore an analysis of the significance of the error correction terms helps ascertain the direction of long run Granger causality, while the joint-significance of lagged explanatory variables determines the direction of short run Granger causality.

4.2 Procedure

The methodology adopted in the current study was based on the procedure utilised by Shiu & Lam (2004). First, the optimal number of lags in the underlying Vector Auto Regression (VAR) shown in Equation (2) was determined. Unlike Shiu & Lam (2004), who used the Akike Information Criterion (AIC) when selecting the optimal lag-length, the Schwarz-Bayesian Information Criterion (SBIC) has been used in this paper. The SBIC places a higher penalty on increasing the number of lagged variables in the model relative to AIC - a desirable attribute when dealing with small samples. Additionally, due to the small sample size, the maximum number of lags in the underlying VAR was limited to four. This is consistent with the approach adopted by Shiu & Lam (2004), as well as intuition - short run effects are likely to be felt within four years of a change to either variable.

Stationarity of the logged series, as well as the first-difference of these logged series, were then tested using the Augmented Dickey Fuller (ADF) test. The optimal lag-length as determined by the SBIC was used to define the number of lags required when conducting this test. Also, due to the clear presence of a time-dependent trend in the logged series, a trend-term was included when applying the ADF test for these series. The main purpose of the test is to ascertain whether a unit root was present in the series. While it is acceptable for a series to be non-stationary in levels, it must stationary when differenced in order to prevent spurious correlation (Granger & Newbold, 1974; Hamilton, 1994).

The Johansen test for co-integration was then applied to ascertain whether a long run co-integrating relationship existed between the variables. Following this test the model as specified by Equations (2), (3), and, (4) was then run, with the number of lags, n, being equal to the optimal lag-length found for the underlying VAR minus one. Note that one lag must be subtracted as Equations (3) and (4) are in first-differences. A final assessment of the appropriateness of the lag-length was then made by using the Lagrange Multiplier (LM) test to check for serial correlation in the residuals - the lag-length was adjusted accordingly if there was evidence of serial correlation.

The long and short run causal relationships were analysed by testing the significance of coefficients in Equations (3) and (4). Long run Granger causal relationships were ascertained by testing the significance of the coefficients on the error-correction terms, α_x and α_y. Short run relationships were determined by testing the joint-significance of the lagged explanatory variables. Specifically, the joint significance of lagged RGRP variables were tested in Equation (3), while the joint significance of lagged ELC values were tested in Equation (4). A statement was then be made regarding the direction of long and short run Granger causality between the two variables.

4.3 Effect of aggregation

The effect that aggregation has on the results obtained from Granger causality tests was investigated by examining the relationship between electricity consumption and GDP at the provincial, electricity-market, and national levels. Intuitively, if a group of adjoining provinces exhibit long run Granger causality in a particular direction, it is expected that the same relationship would be observed when aggregating these provinces and repeating the analysis. A natural way to test this hypothesis is to group Chinese

Figure 7: Electricity markets within China

provinces into their respective electricity markets and aggregate RGRP and electricity consumption data within these regions. At present there exist seven electricity markets in China. The location and geographical size of these markets are illustrated in Figure 7.

The provinces within each electricity market were aggregated by summing their respective RGRP and electricity consumption series. The VECM was then applied to ascertain the long and short run Granger causal relationships between electricity consumption and GRP at the regional level. This enabled the results obtained at the provincial, electricity-market, and national levels to be compared. In comparing the relationships observed between these different levels of aggregation the capability of highly aggregated data to identify prevailing long and short run Granger causal relationships was determined.

4.4 Robustness analysis

The robustness of the results obtained were tested by altering the sample period under consideration. This was accomplished by using a rolling-window approach. The method created a number of sub-samples, each of the same length, re-running the VECM for each sub-sample. If there was little variation in the direction of Granger causality over the different sub-samples, then it suggested that the relationships observed were relatively robust to changes in the sample period.

5 Results

The results obtained from applying the methodology discussed in Chapter 4 are presented in the following section. In order to conduct a completely disaggregated analysis, the VECM was applied to each province, and the results analysed independently. The same procedure was then applied to investigate causal relationships within electricity-market regions, as well as for national level data. For the sake of brevity only results relating to China's national level statistics are explained in detail (a comprehensive set of VECM results for the individual provinces and electricity-market regions can be found in Appendix C). Summary tables and illustrations are presented in order to facilitate the interpretation of results, as well as assist in the comparison of Granger causal relationships observed at different levels of aggregation. The results obtained from ro-

Lag	AIC	SBIC
0	-0.663	-0.565
1	-9.016	-8.721
2	-9.599	-9.109
3	-9.990	-9.303
4	-10.31†	-9.430†

† Minimised AIC and SBIC values, indicating the optimal lag length

Table 1: Lag selection - AIC and SBIC values

bustness checks also are presented, indicating the sensitivity of results to changes in the sample period.

5.1 Analysis for aggregate level data

The underlying VAR, which expresses the relationship between electricity consumption and economic growth in China, is shown in Equation (2). First, the optimal lag-length for this underlying VAR was found by using the SBIC. The values of this criterion for the varying lag-lengths are shown in Table 1.

As an additional check, AIC values are also included in Table 1. From the table it can be seen that the minimum SBIC and AIC values correspond to a lag-length of four - indicating the optimal lag-length.

The logged and first-differenced data were then tested for a unit-root. From Figure 8 it appears that a time-trend is present within the level data, informing the inclusion of a trend-term when conducting the ADF test on the logged series. Also, for the first-differenced series shown in Figure 9, the mean of the series is clearly non-zero. This observation informed the inclusion of a drift-term when conducting the ADF test on the first-differenced series. As the optimal number of lags in the underlying VAR was

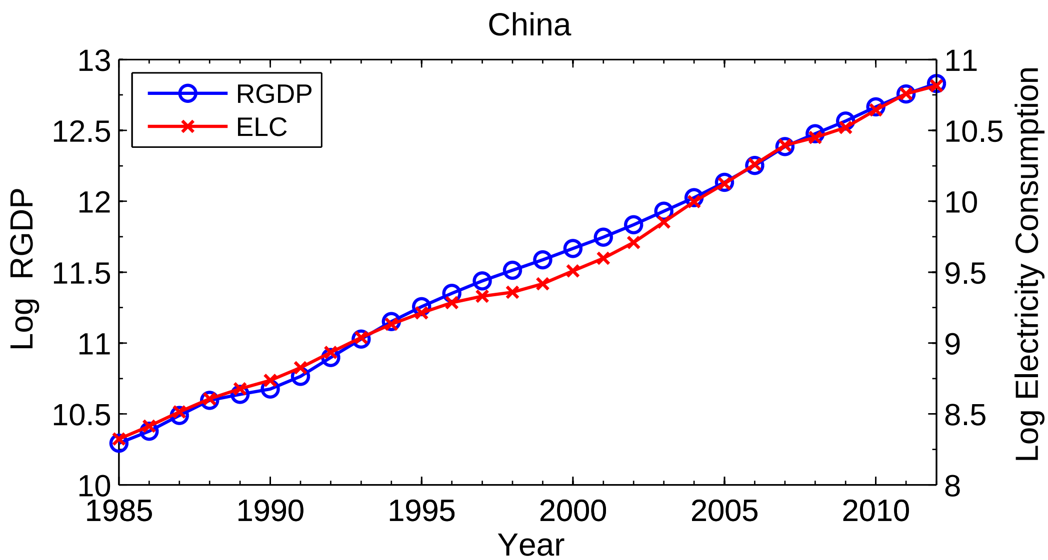

Figure 8: China - Log electricity consumption and log RGDP

four, the same number of lags were included when testing for a unit-root using the ADF test. The resulting p-values of the ADF test are shown in Table 2.

	Levels		**First Difference**	
	Z	**p-value**	**Z**	**p-value**
RGRP	-2.55	0.304	-3.93	0.001
ELC	-1.47	0.841	-2.70	0.008

Null hypothesis: presence of a unit-root

Table 2: China - ADF test

From Table 2 p-values of 0.841 and 0.304 are observed for the logged electricity consumption (ELC) and RGDP series respectively, implying that we should not reject the null hypothesis of the presence of a unit-root. However, for the first-differenced series the p-values are 0.008 and 0.001 for ELC and RGDP respectively, suggesting that we reject the null hypothesis of the presence of a unit-root at the 1% level of significance. Having established stationarity in the first-differenced series, it is possible to proceed to the next phase of the analysis and test for co-integration between the variables.

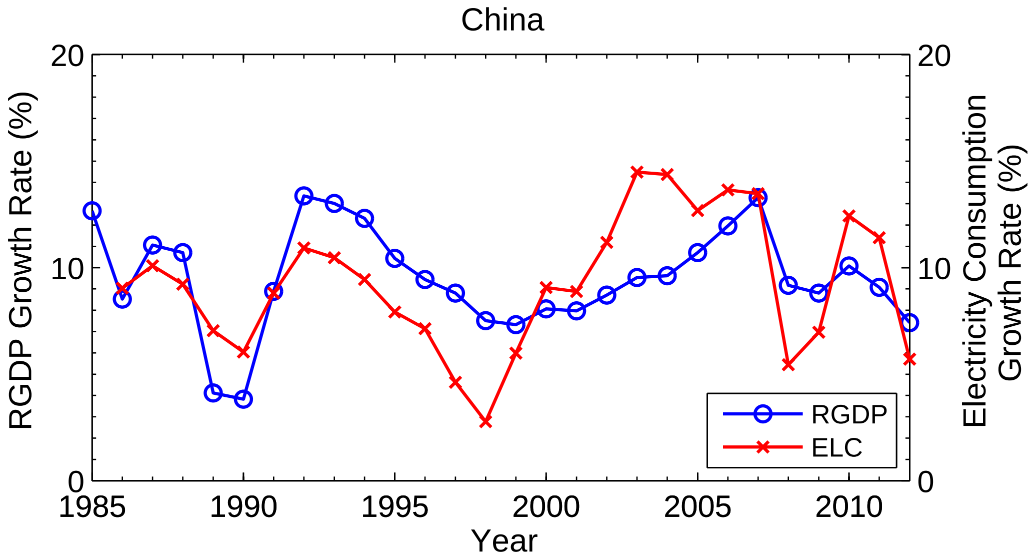

Figure 9: China - ΔELC and $\Delta RGDP$

The Johansen co-integration test assesses whether a linear combination of two or more $I(1)$ series can produce an $I(0)$ series. If this is found to be the case then the series are said to be co-integrated - indicating the presence of a long run relationship between the variables. The Johansen co-integration test was applied to the logged electricity consumption and RGDP series in order to assess the presence of a long run relationship between these variables, with the trace-statistics from this test presented in Table 3. The trace statistics suggests that the null hypothesis of no co-integrating relationship between the two variables is not rejected at the 10% level. The fact that the trace-statistic is reasonably close to the critical value is encouraging as it is known that the Johansen test for co-integration has low-power in small samples (Mallory & Lence, 2012; Johansen, 2002). The literature overwhelmingly shows that these two series are co-integrated for China, therefore this test is used as a guide only (Payne, 2010*a*).

Following the determination of stationarity in the first-differenced series the VECM was applied to the data. The results from the VECM are shown in Table 4.

No. co-integrating equations	LL	Trace	Critical values 10%	5%
0	136.3	10.9	13.33	15.41
1	141.4	0.743	2.69	3.76
2	141.8			

Table 3: China - Johansen test for co-integration

	Dependent variable ΔRGDP	ΔELC
Constant	0.044	-0.006
	(0.209)	(0.894)
ECT_{t-1}	0.033	0.228***
	(0.597)	(0.008)
ΔRGDP		
L1	0.895***	-0.516
	(0.001)	(0.181)
L2	-0.891***	0.007
	(0.006)	(0.987)
L3	0.034	-0.812**
	(0.910)	(0.048)
ΔELC		
L1	-0.076	1.03***
	(0.652)	(0.000)
L2	0.162	-0.682**
	(0.478)	(0.030)
L3	0.214	0.973***
	(0.288)	(0.000)

P-values in parentheses

Table 4: China VECM results

The first column of Table 4 shows the independent variables included in each of the models described by Equations (3) and (4). The second column displays the coefficients and p-values for these explanatory variables with ΔELC as the dependent variable, while the third column has $\Delta RGDP$ as the dependent variable. The ECT_{t-1} terms represent the estimated coefficients for the error-correction terms, while the respective lags of each explanatory variable are denoted by L1, L2, and L3.

Prior to analysing the coefficients, the lag specification is checked by conducting the

LM test for serial correlation. The p-values corresponding to the null hypothesis of no serial correlation in the residuals are shown in Table 5.

Lag	**p-value**
1	0.189
2	0.436
3	0.379
4	0.760

Table 5: China - LM test for serial correlation

At the highest lag order the p-value is 0.760. This indicates that there is no evidence of serial correlation in the residuals, and that the lag-length specified is acceptable. Following this test the coefficients in Table 4 were analysed to ascertain the direction of Granger causality.

An analysis of the error-correction terms in Table 4 showed that ECT_{t-1} was only significant at the 1% level with ΔELC as the dependent variable. Therefore electricity consumption is the series which responds most to restore the long run equilibrium if a disequilibrium manifests itself - indicating that the direction of long run Granger causality runs in RGDP to electricity consumption.

In order to determine the direction of short run Granger causality the joint significance of lagged explanatory variables in Equations (3) and (4) were determined using an F-test. The results from these F-tests are presented in Table 6.

		Dependent variable	
		ΔRGDP	ΔELC
Explanatory variable	ΔRGDP	-	0.021
	ΔELC	0.238	-

P-values for joint F-test reported
(null hypothesis: lagged variables are jointly insignificant)

Table 6: China - Short run Granger causality F-tests

From Table 6 it can be observed that lagged RGRP variables are jointly significant when ΔELC is the dependent variable, however lagged ΔELC variables are not jointly significant when $\Delta RGDP$ is the dependent variable. This suggests that past values of RGDP contain information that can be used to predict future values of ELC, but not vice versa. Therefore there is evidence of uni-directional Granger causality running from RGDP to electricity consumption in the short, as well as the long run.

5.2 Results summary

The analysis procedure was repeated for all the provinces and electricity market regions. A summary of the main results are presented in Table 7.

	ADF Test				Johansen	Granger Causality	
	RGRP		Elec. Con.		Trace Stat*		
	Lvl	**FD**	**Lvl**	**FD**		**Short run§**	**Long run**
China	0.304	0.001***	0.841	0.008***	10.9	RGRP⇒ELC	RGRP⇒ELC
North China Power Grid	0.002***	0.026**	0.754	0.032**	4.05	RGRP⇎ELC	RGRP⇒ELC
Beijing	0.452	0.007***	0.502	0.001***	20.1***	-	RGRP⇐ELC
Tianjin	0.075*	0.041**	0.950	0.035**	9.93	RGRP⇎ELC	RGRP⇐ELC
Hebei	0.001***	0.001***	0.686	0.023**	10.8	RGRP⇒ELC	RGRP⇒ELC
Shanxi	0.131	0.006***	0.485	0.000***	17.3**	-	RGRP⇐ELC
Shandong	0.083*	0.001***	0.590	0.001***	4.84	-	RGRP⇎ELC
Northwest China Power Grid	0.997	0.287	0.874	0.101	54.7***	RGRP⇎ELC	RGRP⇐ELC
Shaanxi	0.984	0.006***	0.950	0.010**	16.4**	-	RGRP⇔ELC
Gansu	0.807	0.104	0.814	0.075*	35.4***	RGRP⇒ELC	RGRP⇐ELC
Qinghai	0.313	0.164	0.527	0.002***	22.0***	RGRP⇔ELC	RGRP⇔ELC
Ningxia	0.949	0.043**	0.711	0.001***	31.6***	-	RGRP⇐ELC
Xinjiang	0.523	0.034**	1.000	0.879	8.92	RGRP⇎ELC	RGRP⇒ELC
Northeast China Power Grid	0.711	0.127	0.936	0.044**	6.0	RGRP⇎ELC	RGRP⇒ELC
Inner Mongolia	0.382	0.079*	0.866	0.046**	7.23	RGRP⇒ELC	RGRP⇒ELC
Liaoning	0.936	0.034**	0.873	0.055*	18.3**	RGRP⇒ELC	RGRP⇒ELC
Jilin	0.963	0.002***	0.770	0.000***	12.7	-	RGRP⇐ELC
Heilongjiang	0.175	0.115	0.444	0.014**	16.8**	RGRP⇒ELC	RGRP⇔ELC
East China Power Grid	0.024**	0.008***	0.520	0.047**	4.84	RGRP⇎ELC	RGRP⇎ELC
Shanghai	0.185	0.001***	0.576	0.011**	19.5**	RGRP⇒ELC	RGRP⇒ELC
Jiangsu	0.075*	0.001***	0.570	0.046**	5.35	RGRP⇎ELC	RGRP⇒ELC
Zhejiang	0.138	0.012**	0.483	0.062*	5.14	RGRP⇎ELC	RGRP⇎ELC
Anhui	0.238	0.025**	0.898	0.066*	9.04	RGRP⇎ELC	RGRP⇒ELC
Fujian	0.002***	0.003***	0.279	0.009***	17.1**	RGRP⇐ELC	RGRP⇐ELC
Central China Power Grid	0.839	0.023**	0.738	0.002***	28.3***	-	RGRP⇐ELC
Jiangxi	0.991	0.087*	0.915	0.030**	5.97	RGRP⇎ELC	RGRP⇒ELC
Henan	0.446	0.016**	0.428	0.028**	9.05	RGRP⇎ELC	RGRP⇐ELC
Hubei	0.192	0.027**	0.869	0.035**	6.95	RGRP⇎ELC	RGRP⇎ELC
Hunan	0.792	0.025**	0.351	0.011**	32.2***	RGRP⇐ELC	RGRP⇐ELC
Sichuan†	0.945	0.058*	0.273	0.000***	28.6***	-	RGRP⇐ELC
Southern China Power Grid	0.010**	0.008***	0.029**	0.002***	21.8***	RGRP⇒ELC	RGRP⇒ELC
Guangdong	0.643	0.011**	0.743	0.073*	18.4**	RGRP⇔ELC	RGRP⇐ELC
Guangxi	0.917	0.001***	0.118	0.031**	10.9	RGRP⇎ELC	RGRP⇐ELC
Guizhou	1.000	0.389	0.105	0.002***	24.8***	RGRP⇎ELC	RGRP⇐ELC
Yunnan	0.995	0.111	0.755	0.043**	11.1	RGRP⇎ELC	RGRP⇐ELC

† Data for Sichuan and Chongqing are summed together

§ No entry indicates that only error-correction terms were included in the model

* Null hypothesis of no co-integrating relationship between electricity consumption and real economic growth
P-values are reported for the ADF test (null hypothesis: presence of a unit-root)
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 7: Results summary

It can be observed that, even after first-differencing, several regions exhibit evidence of a unit-root in their electricity consumption and RGRP series. However, once these series were de-trended and the ADF test re-applied, evidence of the unit-root vanished - indicating that these series were in fact stationary. Another important observation is the lack of evidence supporting the existence of a co-integrating relationship between electricity consumption and GRP for number of provinces. One potential explanation for this is the Johansen test's low-power in small samples (Johansen, 2002; Mallory & Lence, 2012). Even if evidence for co-integration was not found, the VECM was still utilised. The fact that the literature strongly supports the presence of co-integration between electricity consumption and GDP/GRP, as well as a majority of provinces in the sample showing evidence for co-integration between these variables, suggests the inability to reject the null hypothesis of no co-integrating relationship may be due to Johansen test's limitations in small samples rather than the absence of a long run relationship. It is important to note that a number of studies question the necessity of co-integration as a pre-condition when implementing error-correction models (Keele & De Boef, 2004; Beck, 1992; Williams, 1992). Therefore, even if the variables are truly not co-integrated, justification for the use of the VECM in such a situation can still exists.

The direction of Granger causality at the provincial level in the short and long run can be better visualised through the use of maps, as shown in Figures 10 and 11. The causal relationships between variables are illustrated through the use of different colours, with legends below the respective figures defining their meanings.

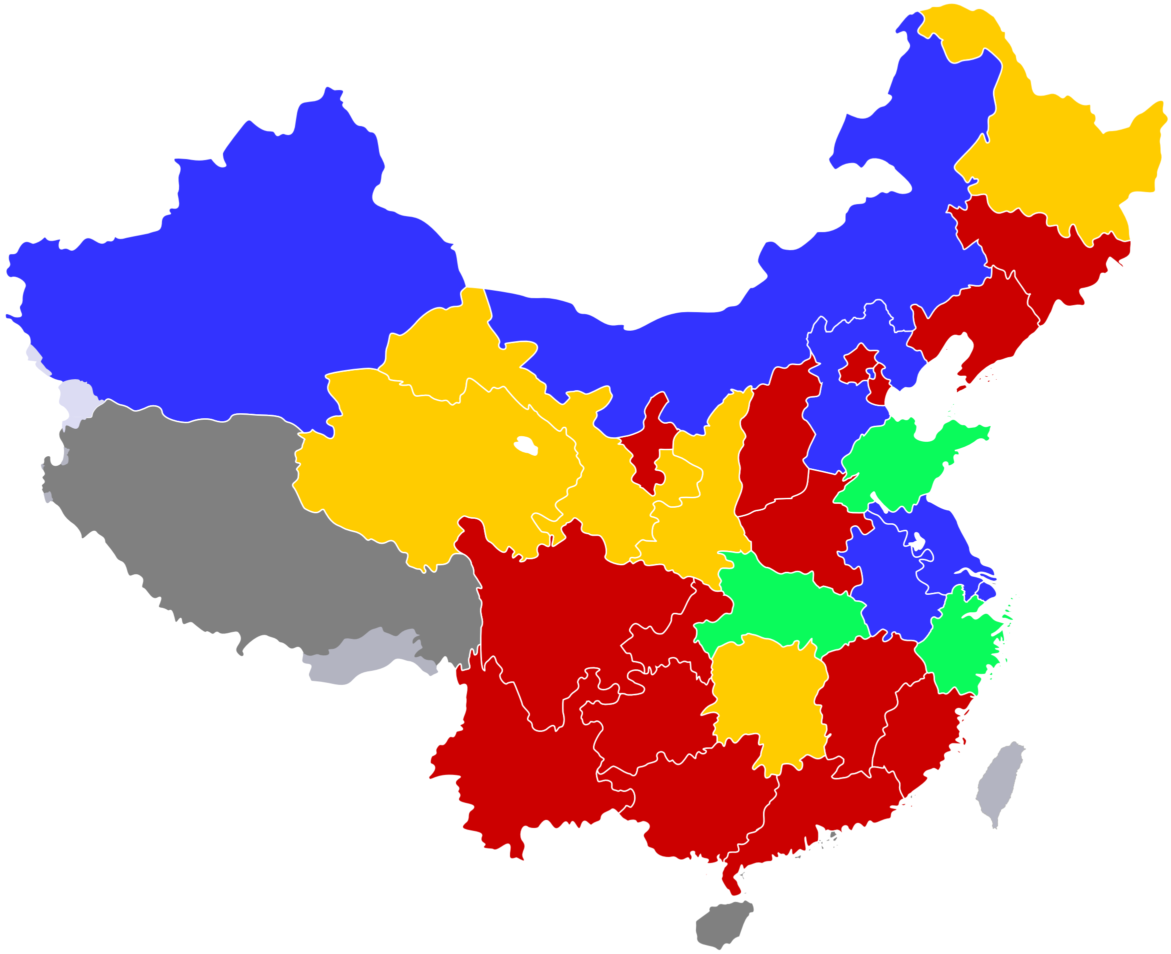

Figure 10: Long run causal relationship between RGRP and Electricity Consumption

Direction of Granger Causality	**Colour**
RGRP$\Leftrightarrow$ELC	
RGRP$\Leftarrow$ELC	
RGRP$\Rightarrow$ELC	
RGRP$\not\Leftrightarrow$ELC	
(not part of analysis)	

Table 8: Long run Granger causality colour key

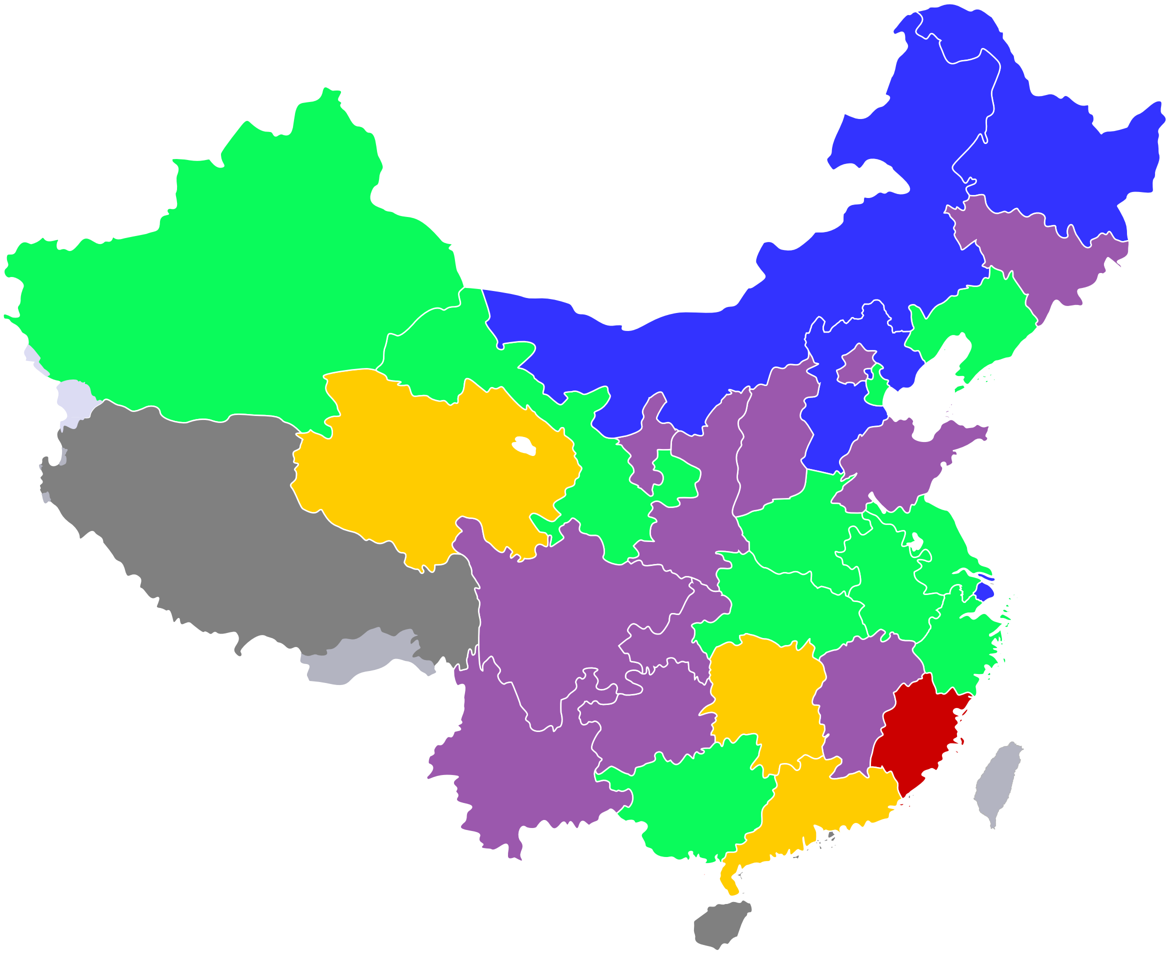

Figure 11: Long run causal relationship between RGRP and Electricity Consumption

Direction of Granger Causality	**Colour**
RGRP⇔ELC	(yellow)
RGRP⇐ELC	(red)
RGRP⇒ELC	(blue)
RGRP⇎ELC	(green)
(no lagged RGRP or ELC coefficients)	(purple)
(not part of analysis)	(grey)

Table 9: Short run Granger causality colour key

A reasonably clear pattern emerged when analysing the long run Granger causal relationships shown in Figure 10. In Southern China the direction of long run Granger causality can be seen to run from electricity consumption to RGRP. The converse appears to be true in the northern and western parts of the country, especially for Xinjiang and Inner Mongolia. It is also interesting to note that bi-directional causality is observed to exist for a number of provinces in the centre of the country - indicative of a transition region existing between the North and South. Also, the fact that a number of adjoining provinces exhibit similar long run relationships is promising - intuitively, provinces located close together are likely to have to similar characteristics and long run relationships.

The pattern is less clear when analysing short run Granger causal relationships. This is partly due to the SBIC determining the optimal lag-length as being one in the underlying VAR for a number of provinces. This single lag is eliminated when first-differencing the series to estimate the VECM, hence an inability to observe short run Granger causal relationships for these provinces. The provinces for which short run Granger causal relationships can be observed exhibit an unclear pattern with respect to the direction of the causality. Northern provinces, such as Heilongjiang and Inner Mongolia, show evidence of Granger causality running from RGRP to electricity consumption - the same direction observed for the long run relationship. This is in contrast to the centre of the country where there exists a band of provinces, from the east-coast to the north-west, for which no short run Granger causal relationships are observed. This is again in contrast to southern provinces, such as Guangdong and Hunan, which exhibit evidence of bi-directional causality between the variables. Interestingly, uni-directional causal relationships running from electricity consumption to RGRP are much less prevalent relative to the long run relationships, with Fujian being the only province to display evidence of Granger causality running in this direction.

The ability of aggregate data to convey prevailing relationships at the provincial level can be examined by analysing the results in Table 7. Often the direction of long run causality differs between provinces within the same electricity market region - making it difficult to ascertain whether the causal relationship observed at the aggregate level is representative of relationships at the provincial level. However, this is not the case for the China Southern Power Grid, with an analysis of this region yielding compelling results. It can be seen from Table 7 that each province within the market shows the direction of long run Granger causality running from electricity consumption to RGRP. However, when these same provinces are aggregated, and the analysis repeated, the direction of Granger causality is reversed. This result casts doubt on the ability of aggregate data to convey prevailing relationships at the provincial level. Furthermore, the intuition that provinces with large economies will have greater influence on the direction of long run Granger causality than smaller provinces is not supported by the data. This is illustrated by the fact that southern provinces, which are among the largest in terms of RGPR, have Granger causal relationships which are in the opposite direction to that observed when using national level data. This result suggests that aggregate data may suffer from serious limitations when attempting to analyse causal relationships between variables. The following section analyses the robustness of these findings to changes in the sample period under investigation.

5.3 Robustness

5.3.1 Sample period

A rolling-window approach was used to ascertain the robustness of the long and short run Granger causal relationships observed to changes in the sample period. This approach carries out the same analysis on sub-samples of the dataset, with each sub-sample spanning a different time period. This method was implemented by first removing the last six years of the original sample, creating a sub-sample of data spanning the years 1985-2006. The VECM was then applied to this sub-sample, and the direction of short and long run Granger causality obtained. The years in the sub-sample were then incrementally adjusted, with the second sub-sample containing data for the years 1986-2006. This process of incremental adjustment was repeated until the sub-sample for the years 1991-2012 was analysed. Detailed results of the ADF test, Johansen co-integration test, and detailed Granger causality results for each of these analyses can be found in Appendix C. A summary of the short and long run relationships observed when analysing these different sub-samples are presented in Tables 11 and 10 respectively. The column labels represent the different sample periods being analysed, while the colour key is same as that used for the maps, and is shown in Table 9.

	Direction of long run Granger causality							
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
China	⇒	⇐	⇒	⇒	⇐	⇐	⇐	⇎
North China Power Grid	⇒	⇐	⇐	⇎	⇐	⇎	⇐	⇐
Beijing	⇐	⇐	⇐	⇐	⇐	⇐	⇒	⇒
Tianjin	⇐	⇐	⇐	⇎	⇐	⇐	⇐	⇐
Hebei	⇒	⇔	⇔	⇐	⇐	⇒	⇐	⇐
Shanxi	⇐	⇐	⇔	⇐	⇒	⇒	⇎	⇎
Shandong	⇎	⇐	⇐	⇎	⇎	⇒	⇐	⇒
Northwest China Power Grid	⇐	⇐	⇐	⇐	⇐	⇔	⇔	⇔
Shaanxi	⇔	⇐	⇔	⇔	⇐	⇔	⇔	⇔
Gansu	⇐	⇒	⇐	⇐	⇐	⇐	⇔	⇐
Qinghai	⇔	⇐	⇔	⇔	⇔	⇔	⇔	⇔
Ningxia	⇐	⇔	⇔	⇔	⇔	⇔	⇐	⇔
Xinjiang	⇒	⇒	⇒	⇒	⇒	⇒	⇒	⇒
Northeast China Power Grid	⇒	⇐	⇐	⇐	⇐	⇐	⇐	⇔
Inner Mongolia	⇒	⇔	⇔	⇔	⇔	⇒	⇒	⇒
Liaoning	⇒	⇔	⇒	⇎	⇐	⇐	⇐	⇐
Jilin	⇐	⇒	⇎	⇐	⇐	⇐	⇐	⇐
Heilongjiang	⇔	⇐	⇐	⇐	⇐	⇐	⇐	⇐
East China Power Grid	⇎	⇎	⇎	⇎	⇐	⇎	⇐	⇒
Shanghai	⇒	⇔	⇔	⇐	⇐	⇐	⇎	⇒
Jiangsu	⇒	⇒	⇒	⇒	⇐	⇐	⇒	⇒
Zhejiang	⇎	⇎	⇎	⇎	⇐	⇐	⇐	⇐
Anhui	⇒	⇐	⇔	⇎	⇎	⇐	⇐	⇒
Fujian	⇐	⇐	⇐	⇐	⇐	⇐	⇐	⇐
Central China Power Grid	⇐	⇐	⇐	⇐	⇐	⇎	⇎	⇒
Jiangxi	⇒	⇐	⇐	⇐	⇐	⇐	⇔	⇐
Henan	⇐	⇒	⇒	⇐	⇐	⇐	⇐	⇐
Hubei	⇎	⇐	⇐	⇐	⇎	⇔	⇐	⇐
Hunan	⇐	⇐	⇒	⇒	⇐	⇒	⇔	⇐
Sichuan†	⇐	⇐	⇐	⇔	⇐	⇔	⇔	⇔
Southern China Power Grid	⇒	⇒	⇔	⇒	⇒	⇒	⇒	⇒
Guangdong	⇐	⇐	⇐	⇐	⇐	⇐	⇎	⇔
Guangxi	⇐	⇐	⇒	⇒	⇒	⇔	⇒	⇐
Guizhou	⇐	⇐	⇐	⇐	⇐	⇐	⇐	⇐
Yunnan	⇐	⇎	⇔	⇐	⇔	⇔	⇔	⇔

† Data for Sichuan and Chongqing are summed together

Model number and sample period key

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1985-2012	1985-2006	1986-2007	1987-2008	1988-2009	1989-2010	1990-2011	1991-2012

Colour key

RGRP⇔ELC	RGRP⇐ELC	RGRP⇒ELC	RGRP⇎ELC
(yellow)	(red)	(blue)	(green)

Table 10: Long run Granger causal relationships for different sample periods

	Direction of short run Granger causality							
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
China	RGRP⇒ELC	RGRP⇎ELC	RGRP⇒ELC	RGRP⇒ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC
North China Power Grid	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Beijing	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Tianjin	RGRP⇎ELC	(only ECT terms)	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Hebei	RGRP⇒ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)
Shanxi	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	RGRP⇐ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)
Shandong	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	RGRP⇎ELC	(only ECT terms)	RGRP⇒ELC
Northwest China Power Grid	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Shaanxi	(only ECT terms)	RGRP⇐ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Gansu	RGRP⇒ELC	RGRP⇒ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Qinghai	RGRP⇔ELC	RGRP⇐ELC	RGRP⇔ELC	RGRP⇔ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Ningxia	(only ECT terms)	RGRP⇔ELC	RGRP⇒ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	(only ECT terms)	RGRP⇐ELC
Xinjiang	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC
Northeast China Power Grid	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	RGRP⇐ELC	RGRP⇎ELC	RGRP⇒ELC
Inner Mongolia	RGRP⇒ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC
Liaoning	RGRP⇒ELC	RGRP⇒ELC	RGRP⇒ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)
Jilin	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Heilongjiang	RGRP⇒ELC	RGRP⇒ELC	(only ECT terms)	(only ECT terms)	RGRP⇐ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)
East China Power Grid	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	RGRP⇔ELC
Shanghai	RGRP⇒ELC	(only ECT terms)	RGRP⇒ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	RGRP⇔ELC
Jiangsu	RGRP⇎ELC	(only ECT terms)	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇔ELC	RGRP⇔ELC
Zhejiang	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC
Anhui	RGRP⇎ELC	RGRP⇎ELC	RGRP⇐ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇔ELC
Fujian	RGRP⇐ELC	RGRP⇎ELC	RGRP⇒ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇐ELC
Central China Power Grid	(only ECT terms)	RGRP⇐ELC	RGRP⇎ELC	(only ECT terms)	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC
Jiangxi	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)	(only ECT terms)
Henan	RGRP⇎ELC	RGRP⇐ELC	RGRP⇒ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Hubei	RGRP⇎ELC	RGRP⇐ELC	RGRP⇐ELC	(only ECT terms)	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)
Hunan	RGRP⇐ELC	RGRP⇐ELC	RGRP⇎ELC	RGRP⇒ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇐ELC	(only ECT terms)
Sichuan†	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Southern China Power Grid	RGRP⇒ELC	RGRP⇒ELC	RGRP⇒ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC	RGRP⇔ELC
Guangdong	RGRP⇔ELC	RGRP⇔ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇎ELC	RGRP⇎ELC	RGRP⇎ELC	(only ECT terms)
Guangxi	RGRP⇎ELC	RGRP⇎ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇐ELC	RGRP⇒ELC	(only ECT terms)
Guizhou	RGRP⇎ELC	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)	(only ECT terms)
Yunnan	RGRP⇎ELC	RGRP⇎ELC	RGRP⇒ELC	RGRP⇎ELC	RGRP⇒ELC	RGRP⇒ELC	RGRP⇒ELC	RGRP⇒ELC

† Data for Sichuan and Chongqing are summed together

Model number and sample period key

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1985-2012	1985-2006	1986-2007	1987-2008	1988-2009	1989-2010	1990-2011	1991-2012

Colour key

RGRP⇔ELC	RGRP⇐ELC	RGRP⇒ELC	RGRP⇎ELC	(only ECT terms)
(yellow)	(red)	(blue)	(green)	(purple)

Table 11: Short run Granger causal relationships for different sample periods

It can be observed that the direction of Granger causality is not consistent at the national level for different sub-samples. While Granger causality runs from RGRP to electricity consumption for the full sample, the relationship changes direction several times for the different sub-samples tested. The most striking example of this is the difference in the direction of long run Granger causality obtained for China when the sample period is adjusted from 1985-2006 to 1986-2007. For the first sub-sample long run causality runs from RGRP to electricity consumption, while the 1986-2007 sub-sample yields an opposite result. This sporadic behaviour of the long run relationship was also observed at the electricity market level, but to a lesser extent. Instead of a complete reversal there seems to be a more gradual transition from one direction of causality to another, with this transitional effect seeming to be even more pronounced at the provincial level. Such transitions are not unexpected - the dynamic nature of development within these provinces may well have led to structural changes that have altered the direction of the long run relationship between these variables. However, it was surprising to observe such extreme changes in the long run Granger causal relationship when using national level data.

The ability of aggregate level data to describe prevailing trends at the provincial level is brought further into question as a result of this robustness analysis. The compelling results obtained when analysing the full sample-period for China Southern Grid also hold as the time-period was altered. While Table 10 shows the direction of Granger causality changing for Guangxi and Yunnan for some of the sub-samples tested, these provinces are relatively small compared to Guangdong - with Guangdong having a RGRP almost twice that of Guangxi, Yunnan, and Guizhou combined (NBS, 2015). For a majority of the sub-samples tested, long run Granger causality was observed to run from electricity consumption to RGRP. Given Guangdong's relative size compared to other provinces within the China Southern Grid it is expected that this relationship would be reflected in the direction of Granger causality observed at the electricity-market level. However, this is not the case, with the direction of long run causality at the grid-level contradicting the prevailing trends observed at the provincial level. Therefore, this robustness analysis supports the notion that highly aggregated data may not necessarily reflect the prevailing trends observed at the provincial level, as these inconsistencies persists even when different sub-samples are considered.

The rolling-window robustness analysis also yields interesting findings for the direction of short run Granger causality. Most notably, it appears that lagged electricity consumption and RGRP values contain less information about future values of these respective series as the sub-samples moves forward in time. For example, in the sub-sample spanning the years 1985-2006 a total of 16 provinces are found to contain more than one lag in the underlying VAR. This is contrasted to the sub-sample spanning the years 1992-2012 where only nine provinces contained more than one lag - maps in Appendix D show this transition as the window rolls forward in time. Also, for the provinces which contained more than one lag, the predominant finding was the absence of a short run Granger causal relationship between the variables, denoted by the green entries. This robustness analysis also reveals the limitations of aggregate data to reflect prevailing short run Granger causal relationships between the variables. When conducting an analysis with national level data the direction of short run Granger causality was shown to run from RGDP to electricity consumption. However, only three provinces exhibit this relationship: Hebei, Inner Mongolia, and Shanghai. Therefore these results again raise questions as to the ability of highly aggregated data to accurately reflect prevailing trends observed at the provincial level.

5.4 Discussion

An important finding of this study is the extent to which Granger causal relationships vary across different regions in China. Aggregate level studies are unable to capture this regional heterogeneity, and may overly simplify the complex regional dynamics that exist within the country. Furthermore, this study shows that the aggregation of several series may lead to a significant amount of information being hidden - in some cases leading to contradictory findings between regional and provincial levels. The most striking example of this was observed for the China Southern Grid, where prevailing trends at the provincial level are lost entirely as a result of aggregation. National-level data were also shown to be sensitive to the sample period under investigation - providing a plausible explanation for the differing conclusions drawn by Boqiang (2003) and Shiu & Lam (2004). These robustness tests also revealed some sensitivity in the direction of Granger causality at the provincial level to changes in the sample period. However, these changes are less extreme than those observed at the national level, with a more gradual transition from one Granger causal direction to another observed.

The results also yield interesting findings regarding the time-period over which electricity consumption and RGRP interact. At the national level both short and long run relationships are observed to exist. This is in contrast to the provincial and electricity-grid levels, which generally showed evidence of long run Granger causality but little evidence for short run uni or bi-direction causality. These results suggest that RGRP and electricity consumption interact over extended time periods. Therefore, Government policies affecting the electric power industry would be best placed in a long run development strategy for the country: increased investment in the electric power industry is more likely to affect growth in the long, rather than the short run. It is important to note that this conclusion would not be drawn if national level data were used solely to conduct the analysis, the results of which show a robust short run relationship running from RGDP to electricity consumption. This again brings into question the suitability of such highly aggregated data when conducting Granger causality tests between electricity consumption and economic growth.

The results of the current study also assist in forming a clearer picture of the long run effects of the Central Government's recently announced nationwide emissions trading scheme. Such a scheme is likely to increase the price of electricity and ultimately reduce consumption. Therefore, provinces where electricity consumption is the Granger cause of RGRP are likely to be most affected. The prevalence of long run relationships, in conjunction with the absence of observed short run relationships, suggests that the effects of this policy will be felt in the long rather than the short run. Provinces located in Southern China, such as Guangdong and Hunan, which show evidence of long run Granger causality running from electricity consumption to RGRP, are likely to be negatively affected. These negative effects are also likely to be felt by provinces located within the centre of the country which display evidence of long run bi-directional Granger causality between these variables. Provinces located in the northern and western regions of the country, such as Inner Mongolia and Xinjiang, are likely to be less affected, as the direction of long run Granger causality is from RGRP to electricity consumption.

One question which this paper has not attempted to address is the reasons for regional heterogeneity in the Granger causal relationships observed between electricity consumption and RGDP/RGRP. Previous studies have analysed regional differences between eastern and western provinces under the premise that the level of economic development plays a role in the direction of Granger causality observed; hence a comparison between more developed provinces in the east with underdeveloped provinces in the west (Chuanguo Zhang, 2012). The results of the current analysis challenge the notion that the level of economic development is the primary driver for the different relationships observed, with the results suggesting that a north-south pattern is more pronounced than east-west variation. This suggests that the structure of the provincial economy, not just its level of economic development, may play an important role in determining the direction of Granger causality between these variables. Also, the observed clustering of provinces with similar long run Granger causal relationships, as well as the presence of a transition region, were significant findings in this study.

The transition of provincial economies from an agricultural to a manufacturing base could be one potential explanation for the observed regional variation. In rural, agricultural based provinces, it may be the case that rising incomes lead to increased demand for goods that use electricity. In these regions it would be expected that rising incomes cause an increase in electricity consumption. This may be in contrast to provinces that have large manufacturing industries, such as in southern and eastern China, where electricity consumed by industry predominates residential consumption. In these regions it may be the case that businesses consume electricity to build infrastructure, such as factories, which then produce output in future periods. In this instance electricity consumption precedes economic growth. Both of these scenarios are consistent with the results observed in the current analysis. Rural provinces, such as Xinjiang, show evidence for real incomes preceding electricity consumption, while in southern provinces it is observed that electricity consumption precedes real economic growth. It would be interesting to test this hypothesis, and also analyse other common structural elements that result in similar Granger causal relationships between these variables. Therefore there exist a number of potential avenues for future research in this field.

6 Conclusions

China's rapid expansion has motivated a number of studies to analyse the role electricity consumption plays in the country's development. These studies have typically used national level data when conducting their analyses, with a number of papers yielding conflicting results. Often these inconsistencies are attributed to difference in model specification and the sample period under consideration. This study shows that the use of highly aggregated national level data may be an additional factor to which these inconsistencies can be attributed.

The analysis shows the existence of regional heterogeneity with respect to the long run Granger causal relationship between electricity consumption and economic growth in China. Not only is this regional heterogeneity not captured when using aggregate level data, but there also appears to be an inability of aggregate level data to reflect prevailing trends at the provincial level. The most striking example of this was observed for the China Southern Grid. All provinces within this electricity market exhibited long run Granger causality running from electricity consumption to RGRP, however when aggregated the direction of causality for the region was shown to run in the opposite direction. Furthermore, this incongruous behaviour was robust to the changes in the sample period. Therefore, policy makers should be careful when considering analyses that rely on national level data - a disaggregated provincial level analysis is more appropriate. This result has particular relevance given China's stated intention to establish a nationwide emissions trading scheme by 2017. Such a policy is likely to discourage electricity consumption, with the economic effects of this reduced consumption to differ across provinces.

The findings of this study have implications extending beyond China's electric power industry. The problems associated with aggregation are ubiquitous, and any study using highly aggregated data is likely to be affected. This finding is particularly relevant given the predominance of national level analyses in the literature. The results of this study also emphasise the need for rigorous robustness testing to ascertain the sensitivity of the direction of Granger causality to changes in the sample period. In particular, they highlight the significant impact incremental changes in the sample period can have on the direction of Granger causality observed.

In summary, this paper highlights the potential problems that can arise when using national level data to assess the direction of Granger causality between electricity consumption and economic growth. The results suggest that long run causal relationships derived from aggregate data are sensitive to the time period under analysis, and also have a limited ability to convey prevailing relationships observed at the provincial level. A key finding of the current study was the regional clustering of long run causal relationships, with southern provinces showing evidence of long run Granger causality running from electricity consumption to RGRP, and northern provinces displaying evidence of long run relationships in the opposite direction. Consequently, policy makers should be wary of using highly aggregated data when attempting to ascertain the economic impacts of electricity-conserving policies as the regional effects may vary considerably. These problems associated with aggregation are unlikely to be limited to China. Future research in this field would help to determine the extent to which aggregation affects the results obtained for other countries.

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Appendices

A Data references

Table 12: Data sources

Region	GRP	Electricity Consumption
Beijing	Beijing SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Tianjin	Tianjin SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Hebei	60 Years of New Hebei NBS	CESY 1986 CESY 1989 CESY 1991 Hebei Economic Yearbook 1993 NBS
Shanxi	The Glorious 60 Years of Shanxi Shanxi SY 2011 NBS	The Glorious 60 Years of Shanxi 1949-2009
InnerMongolia	InnerMongolia SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 InnerMongolia SY 1992 InnerMongolia SY 1993 NBS
Liaoning	Liaoning SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Liaoning SY 1993 NBS
Jilin	Jilin SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Heilongjiang	Heilongjiang SY 2011 NBS	CESY 1986 CESY 1989

		CESY 1991 NBS
Shanghai	Shanghai SY 2011 NBS	Glorious 60 Years - Historical Statistics of Shanghai 1949-2009
Jiangsu	Jiangsu SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Zhejiang	Zhejiang SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Zhejiang SY 1996 NBS
Anhui	Sixty Years of Anhui NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Fujian	Fujian SY 2010 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Jiangxi	Jiangxi SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Jiangxi SY 1996 NBS
Shandong	Shandong SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Henan	Henan SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Henan SY 1996 Henan SY 1993 NBS
Hubei	Hubei SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Hubei SY 1995 NBS
Hunan	Hunan SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991

		NBS
Guangdong	Guangdong SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Guangxi	Guangxi SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Hainan	Hainan SY 2010 NBS	Hainan SY 1993 NBS
Chongqing	Chongqing SY 2011	NBS
Sichuan	Sichuan SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Guizhou	Guizhou SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Guizhou SY 1996 NBS
Yunnan	Yunnan SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Yunnan SY 1991 Yunnan SY 1993 Yunnan SY 1994 NBS
Xizang	Tibet SY 2011 NBS	NBS
Shaanxi	Shaanxi SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 NBS
Gansu	60 Years of New China Gansu NBS	CESY 1986 CESY 1989 CESY 1991 Gansu Development Yearbook 1996 NBS
Qinghai	Qinghai SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Qinghai SY 1992 Qinghai SY 1994 Qinghai SY 1996

		NBS
Ningxia	Ningxia SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Ningxia SY 1995 NBS
Xinjiang	Xinjiang SY 2011 NBS	CESY 1986 CESY 1989 CESY 1991 Xinjiang SY 1992 Xinjiang SY 1993 Xinjiang SY 1995 Xinjiang SY 1996 NBS
China	NBS	1986 CESY 1989 CESY 1991 CESY 1994 CSY 1995 CSY 1996 CSY 1997 CSY 2001 CSY 1998 CSY 2000 CSY NBS

Abbreviations:

SY	Statistical Yearbook
CSY	China Statistical Yearbook
CESY	China Energy Statistical Yearbook
NBS	National Bureau of Statistics Website

B Figures

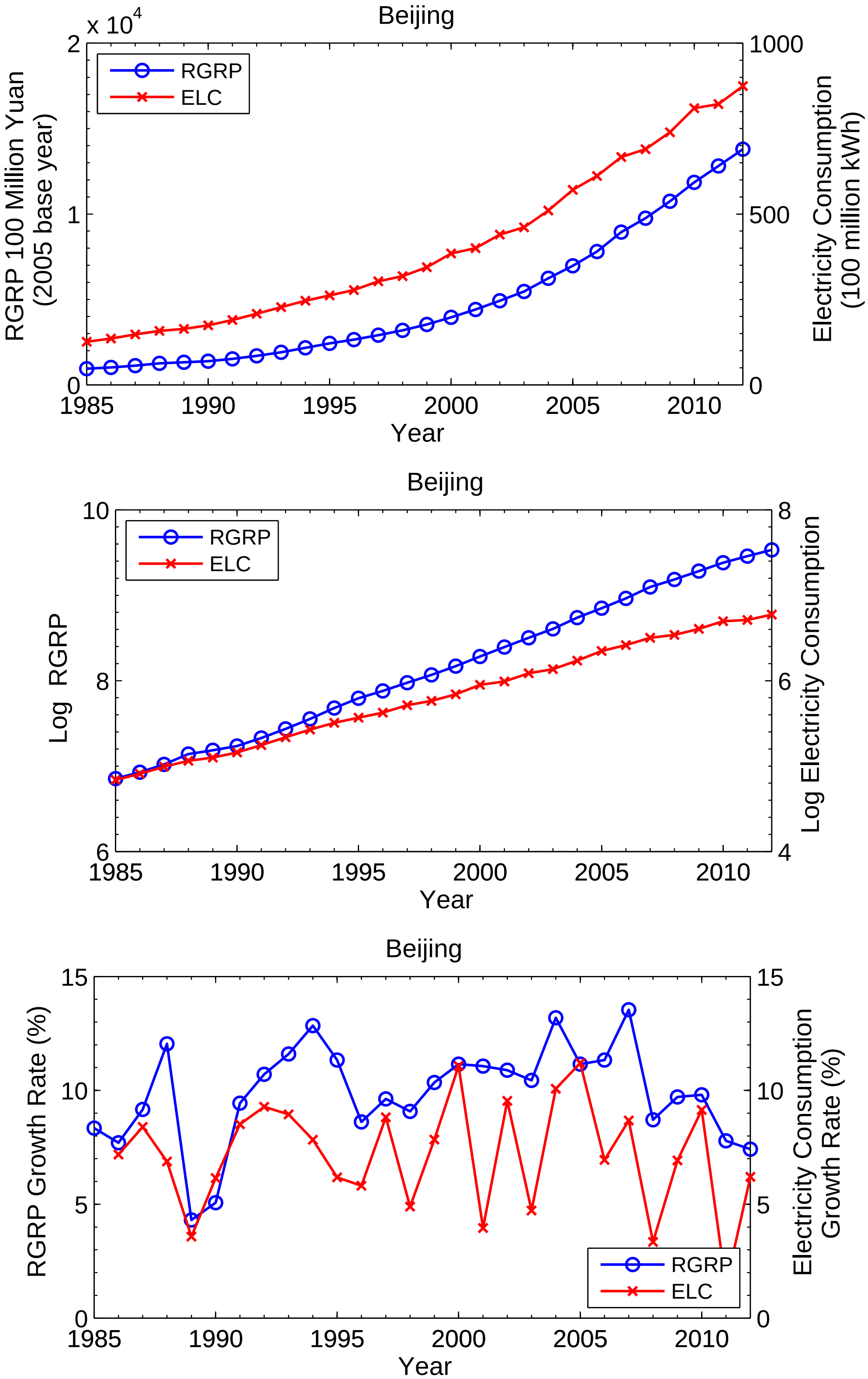

Figure 12: Beijing - Figures

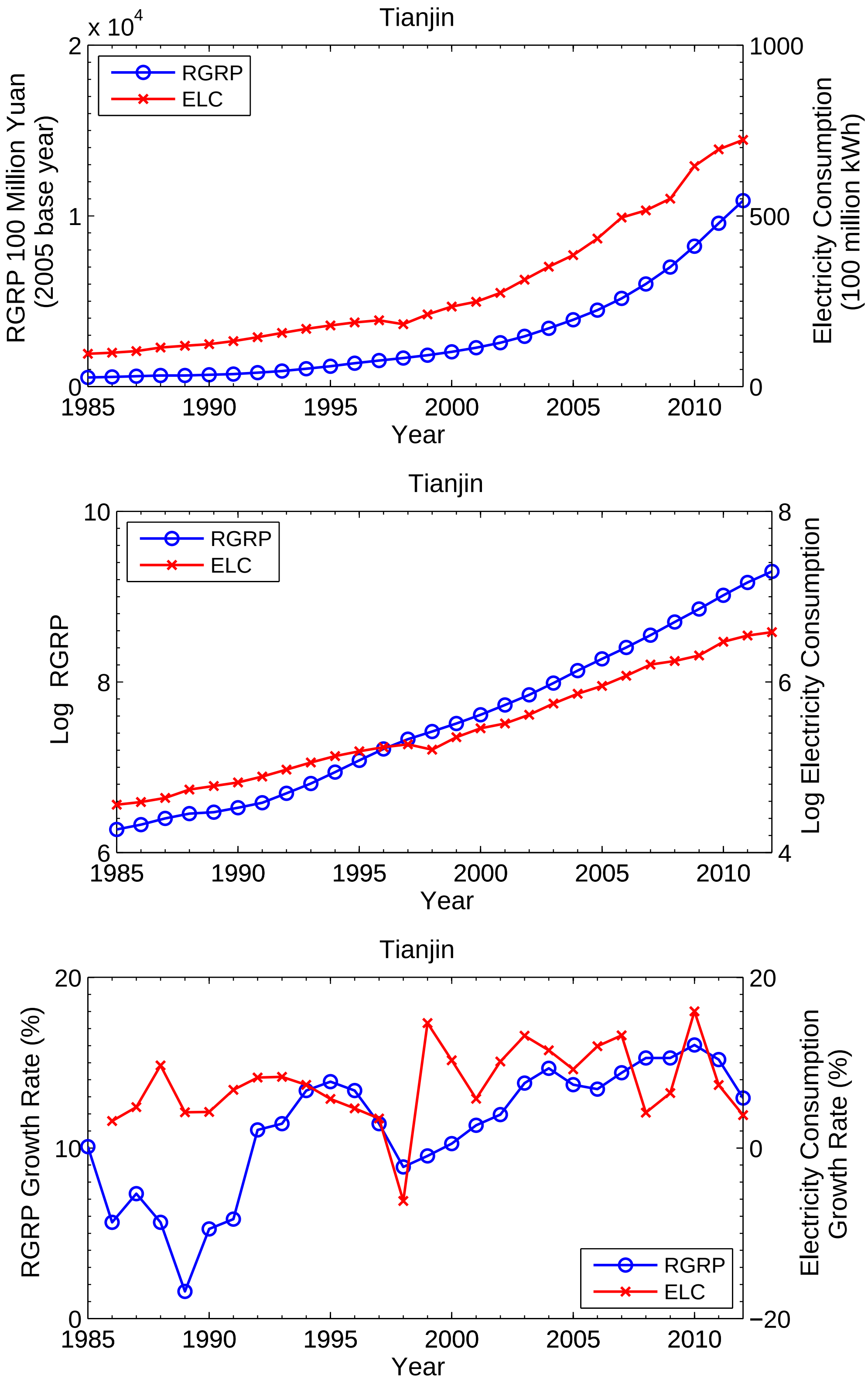

Figure 13: Tianjin - Figures

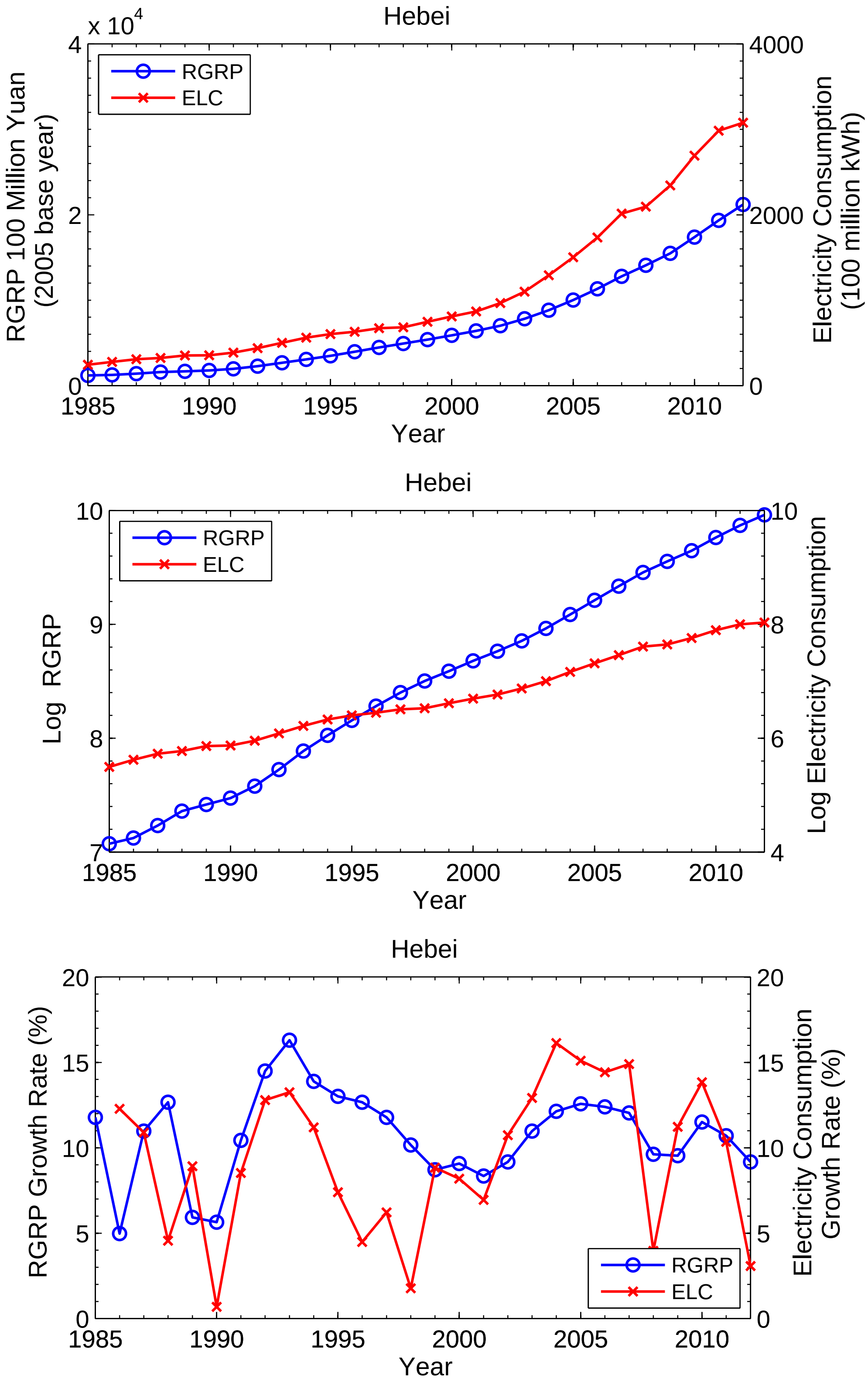

Figure 14: Hebei - Figures

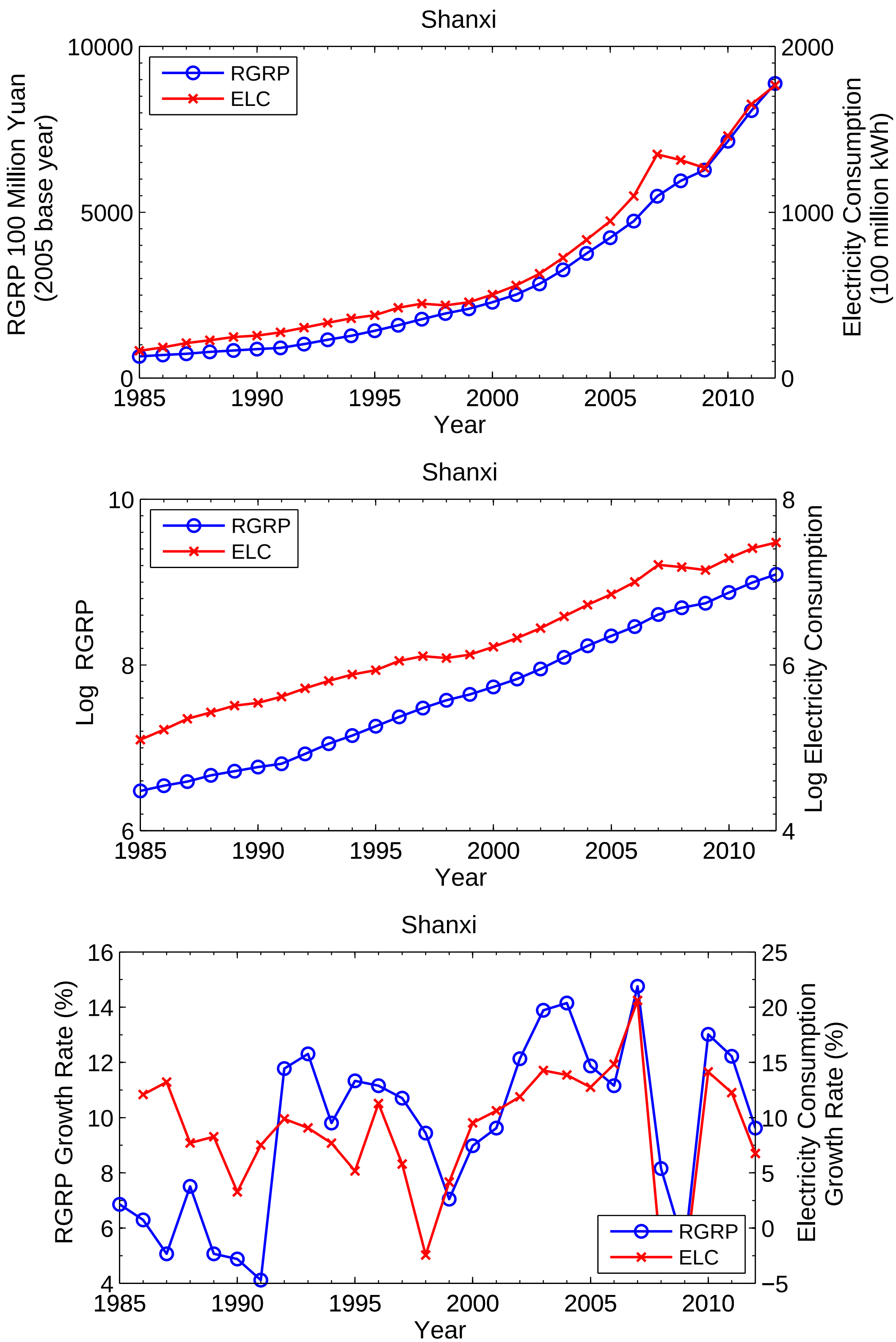

Figure 15: Shanxi - Figures

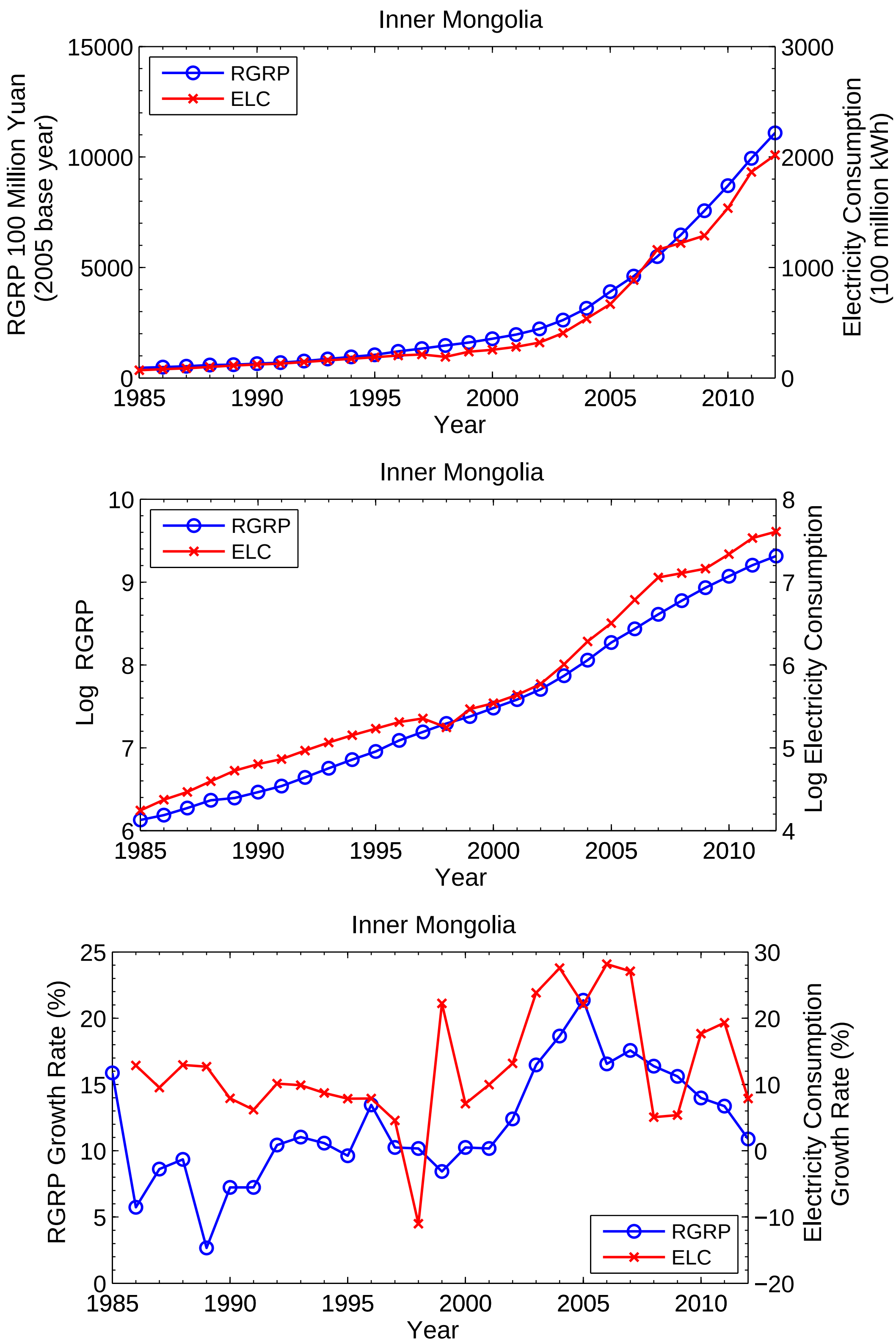

Figure 16: Inner Mongolia - Figures

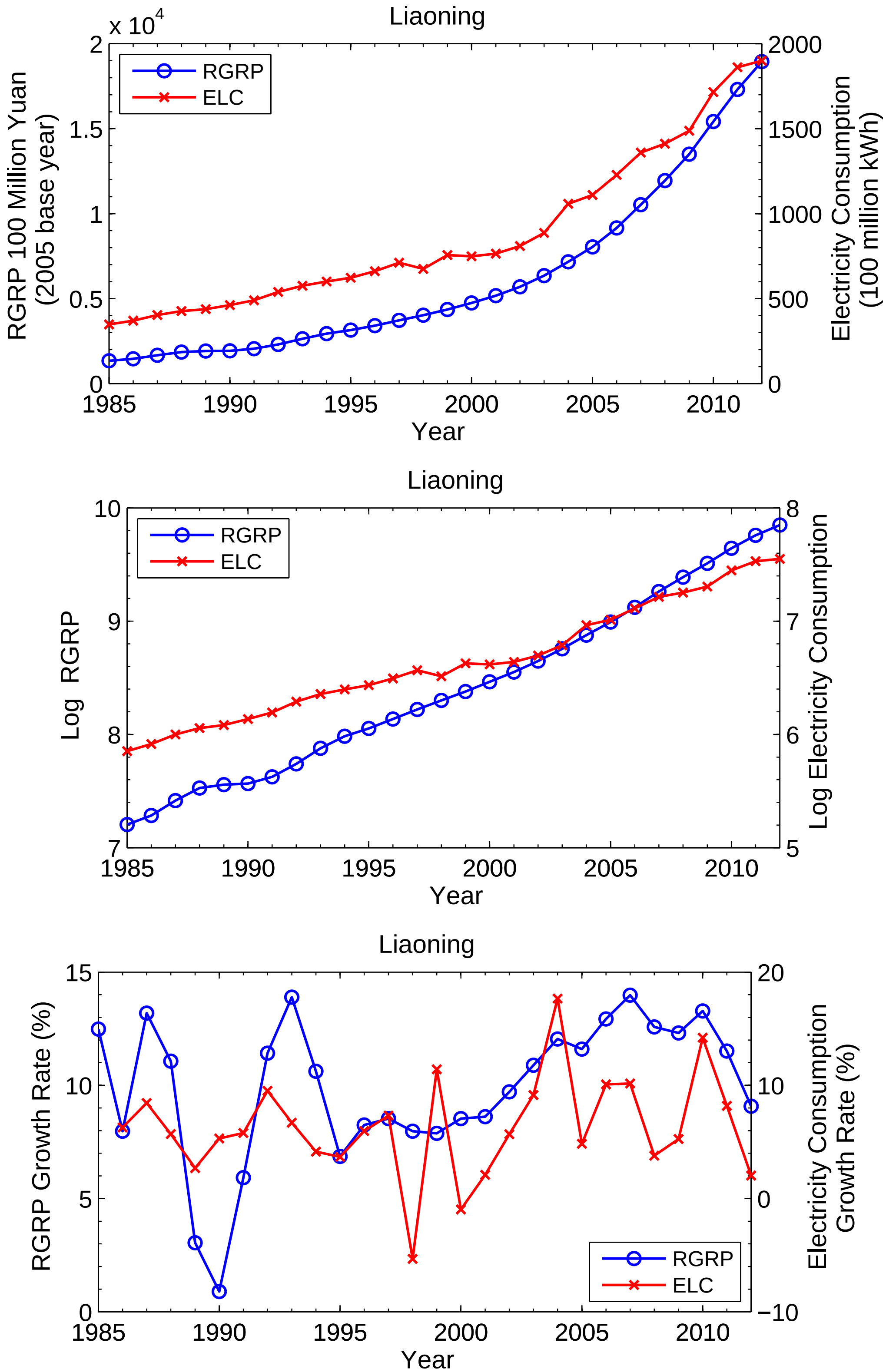

Figure 17: Liaoning - Figures

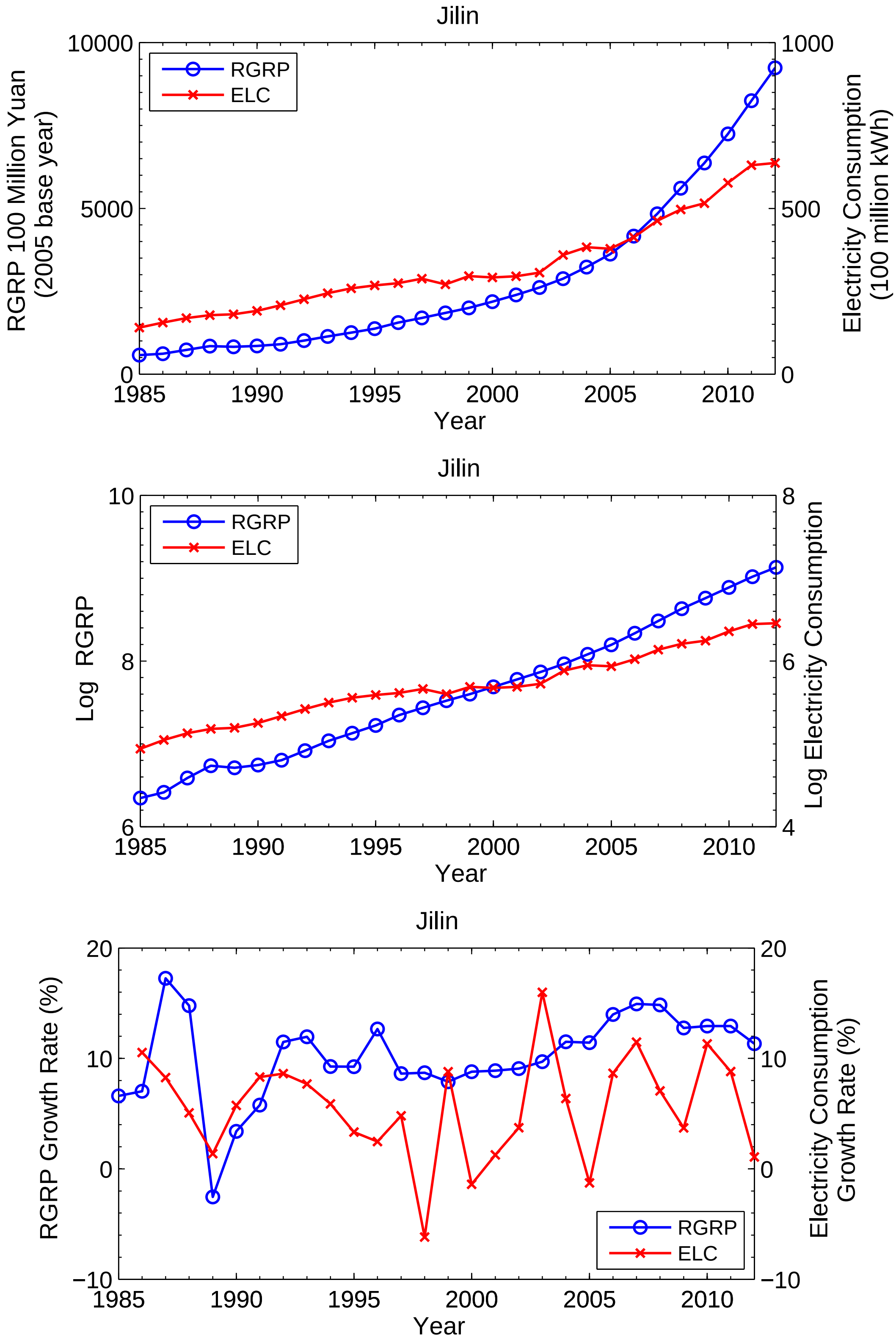

Figure 18: Jilin - Figures

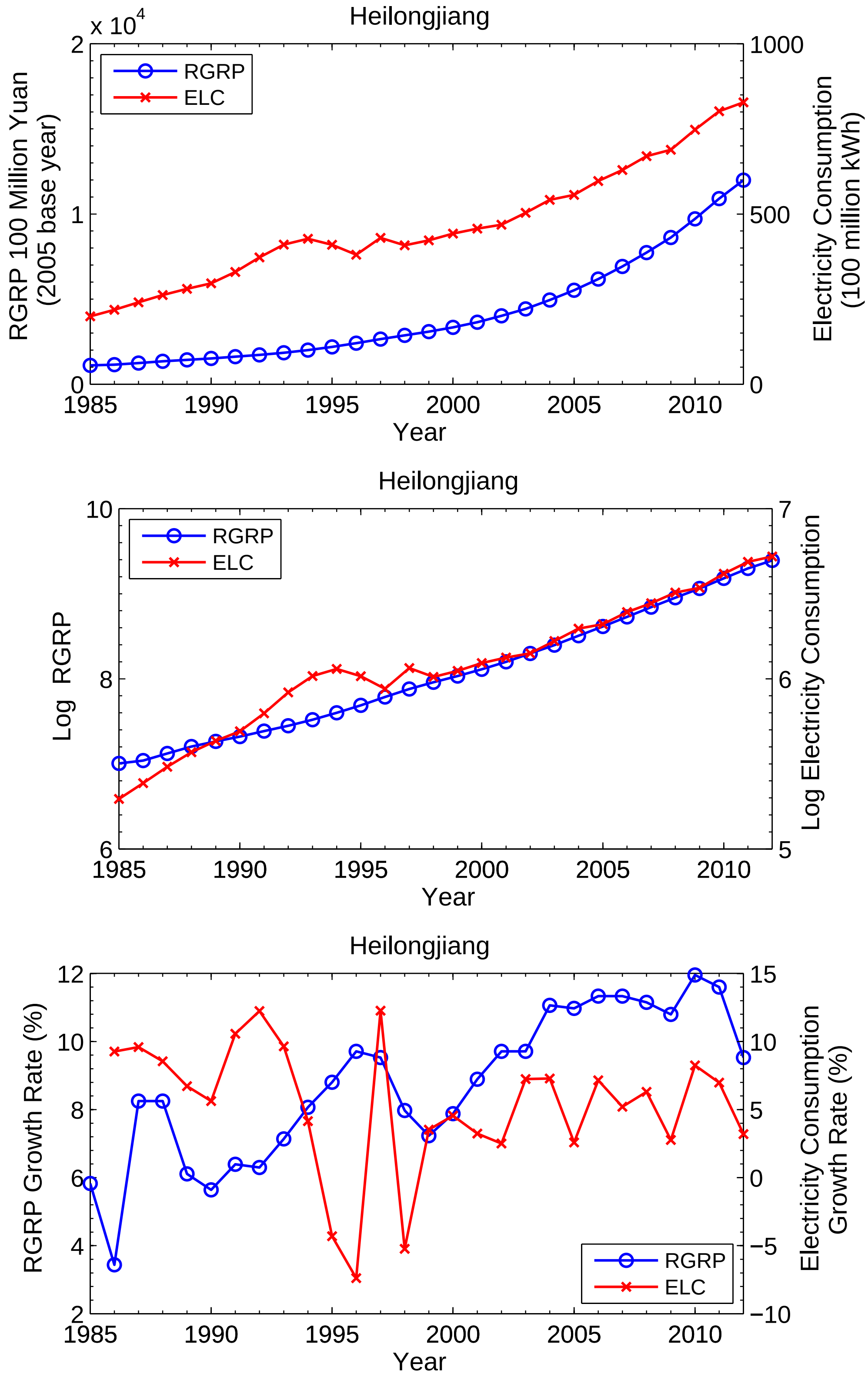

Figure 19: Heilongjiang - Figures

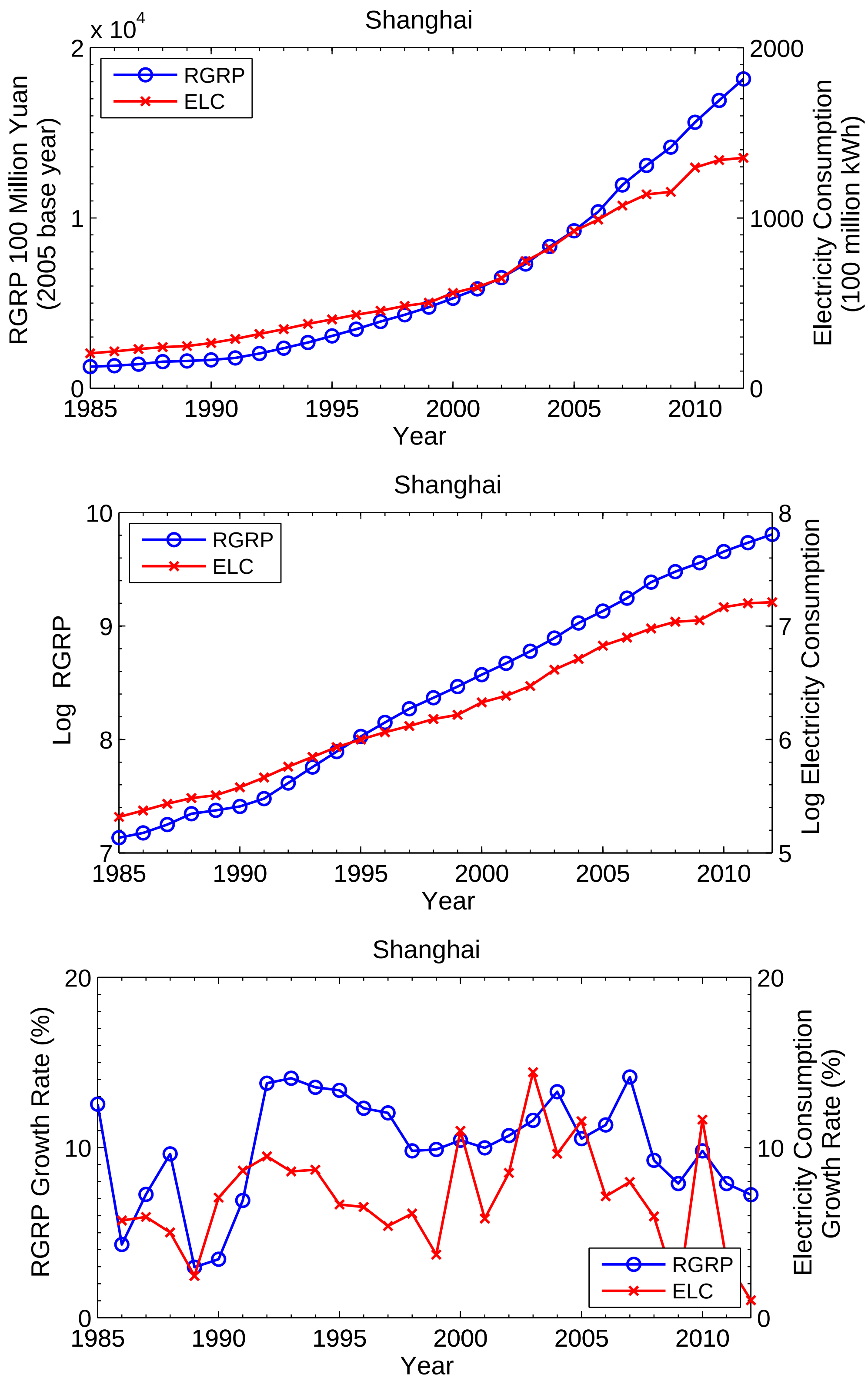

Figure 20: Shanghai - Figures

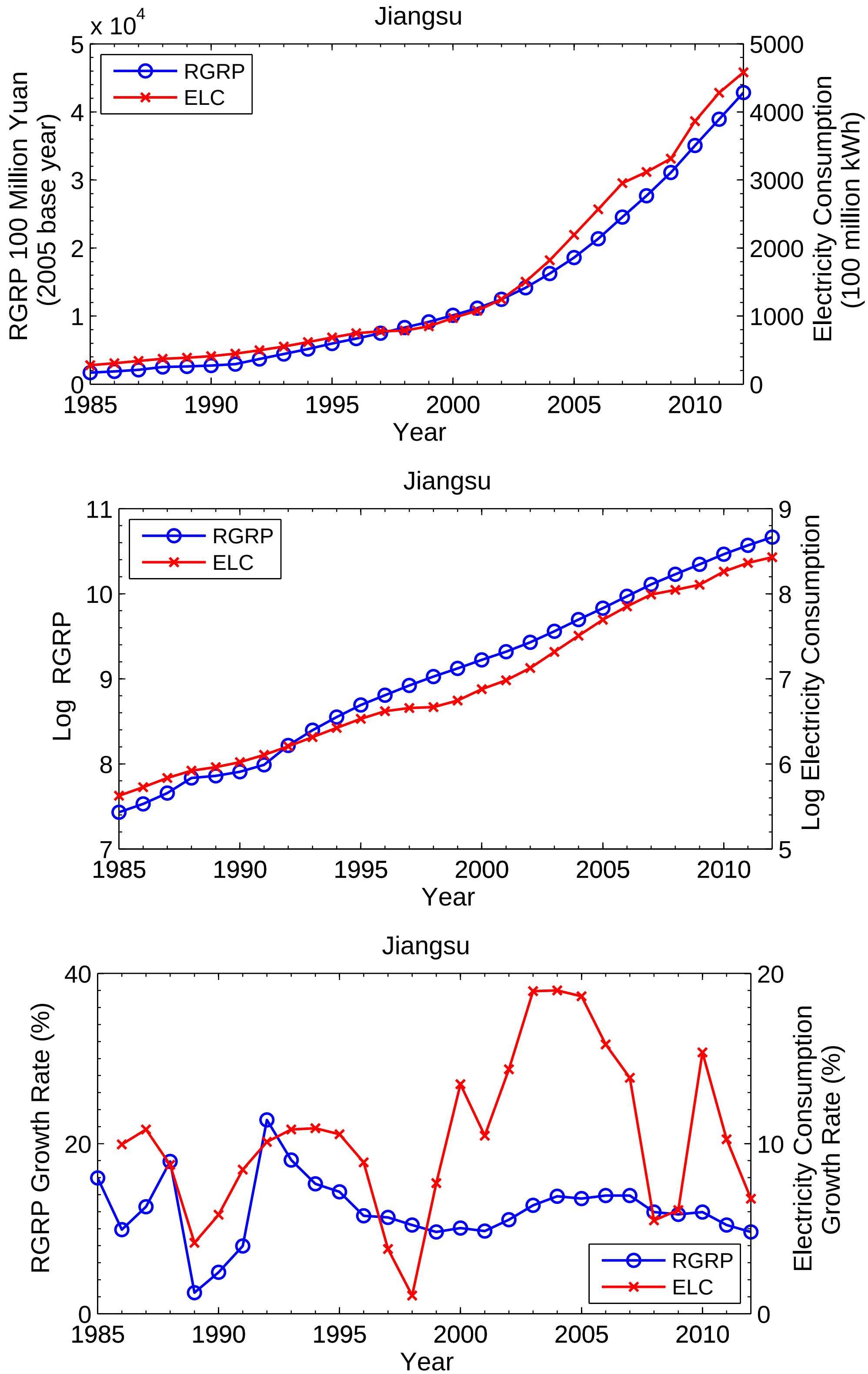

Figure 21: Jaingsu - Figures

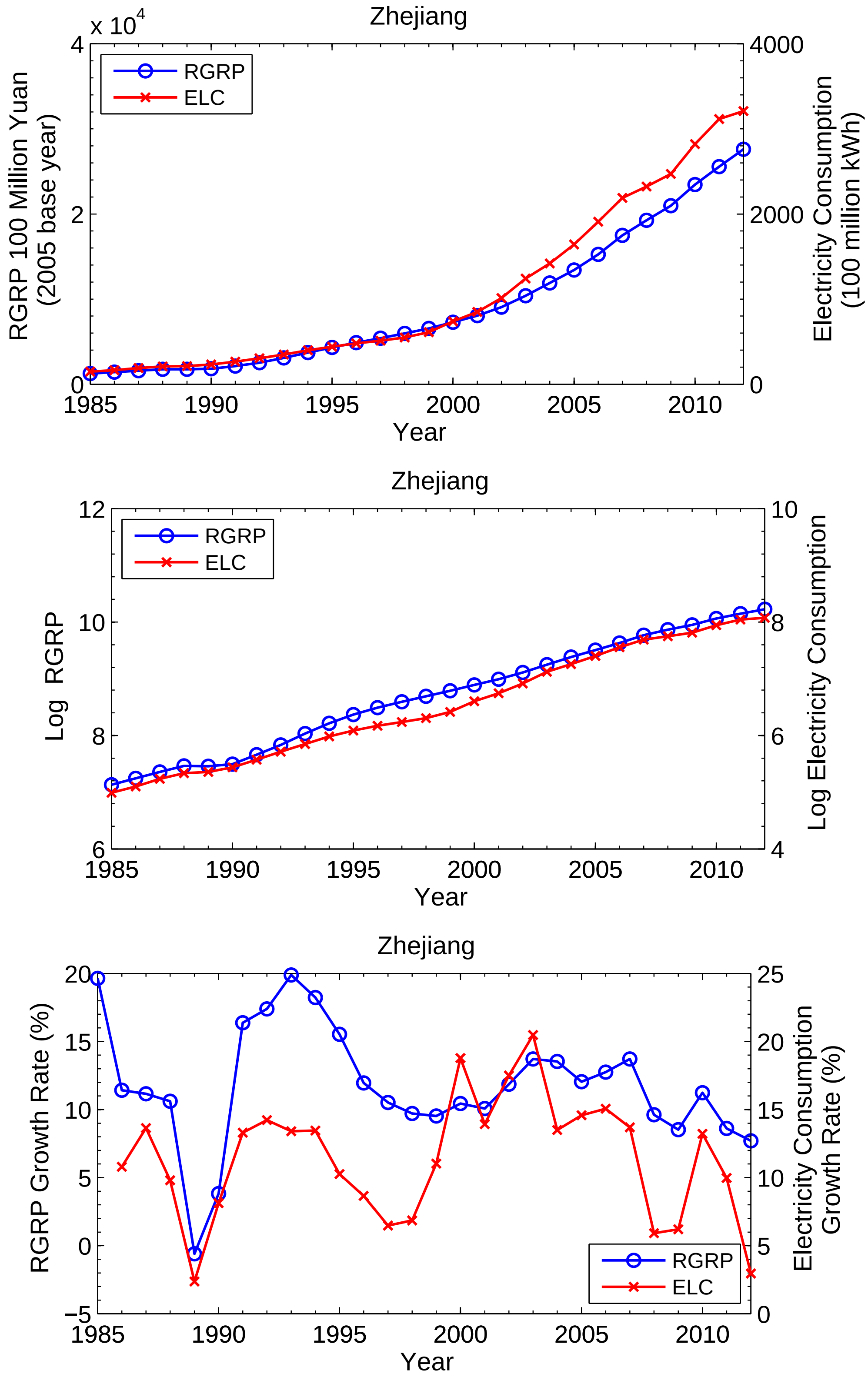

Figure 22: Zhejiang - Figures

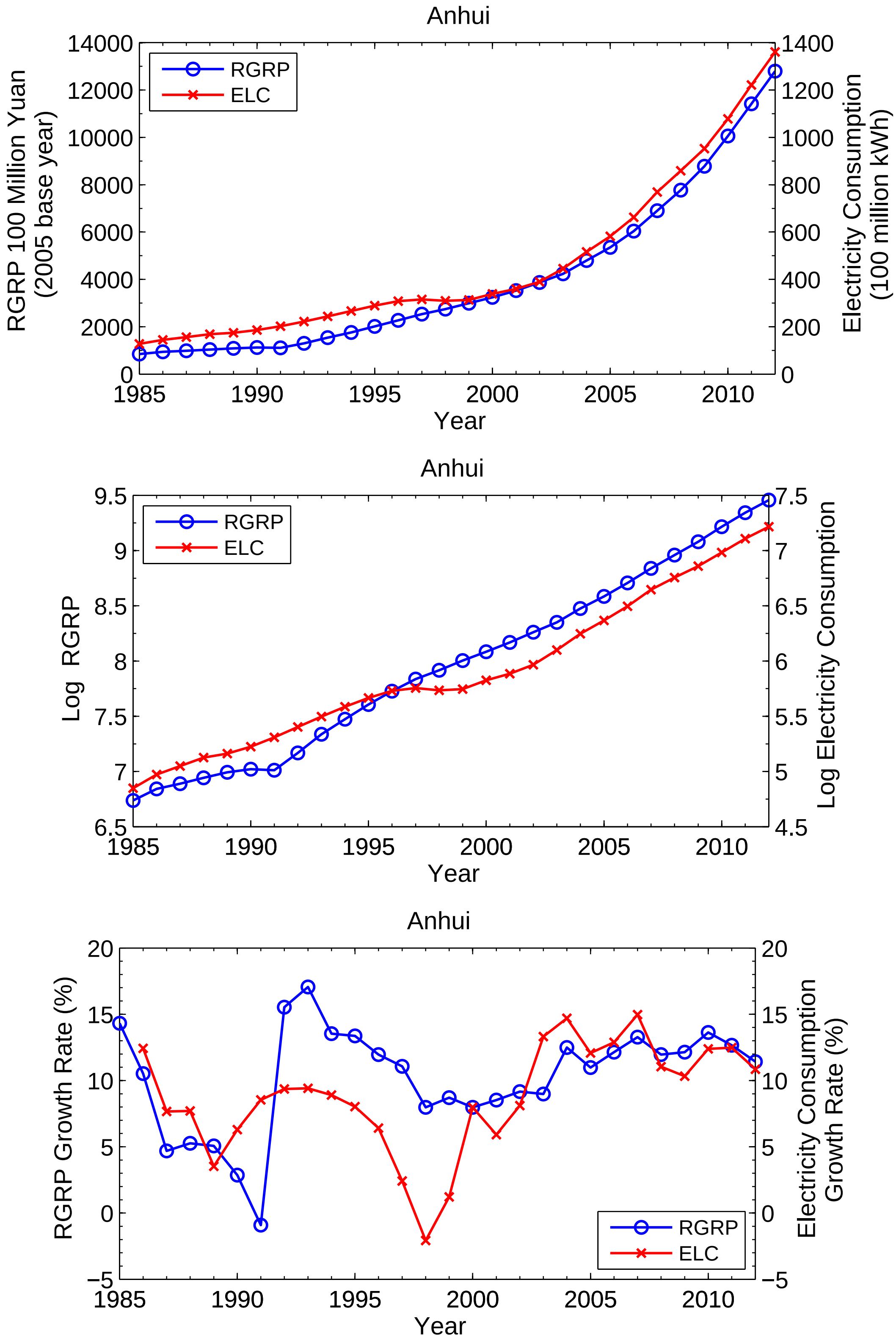

Figure 23: Anhui - Figures

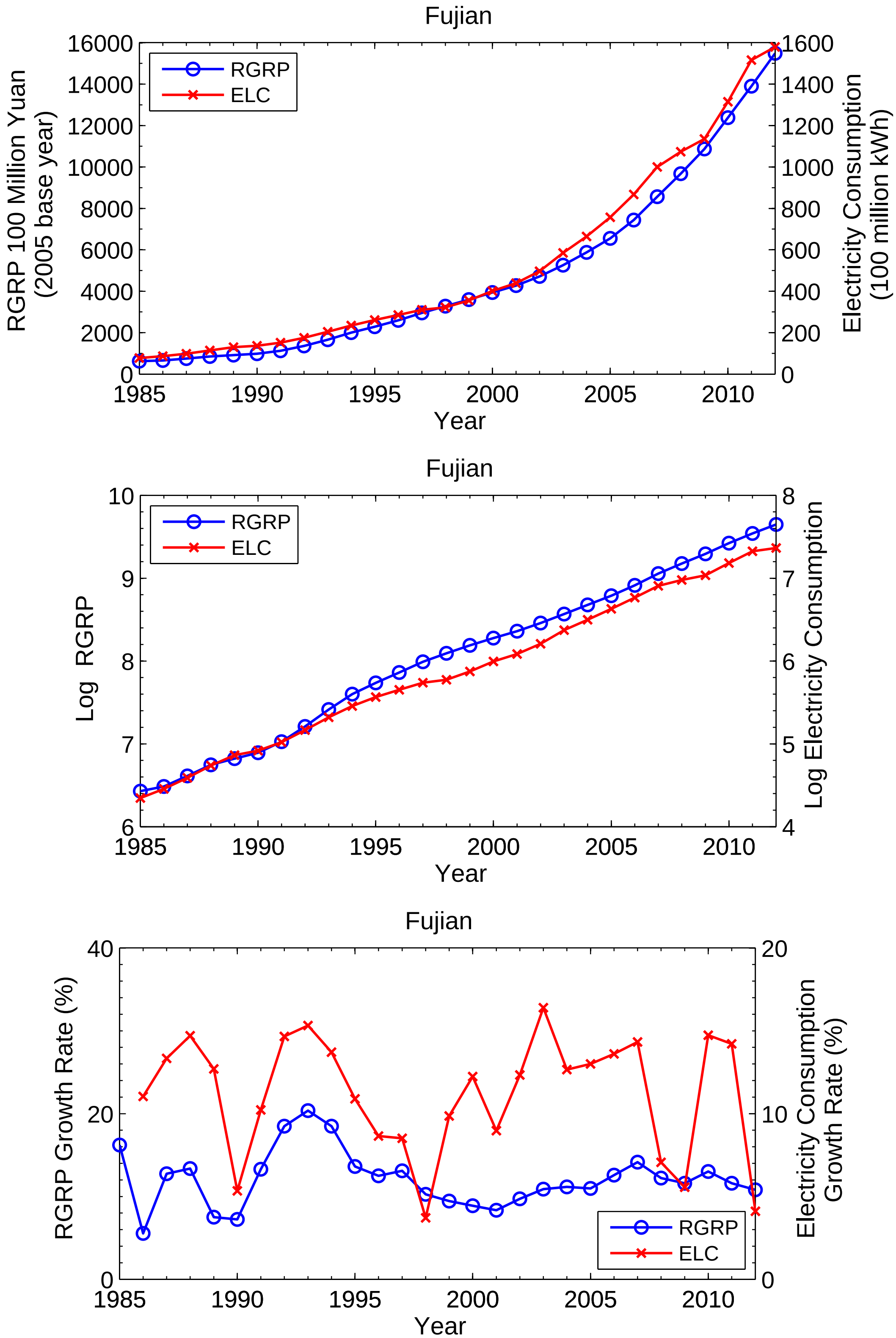

Figure 24: Fujian - Figures

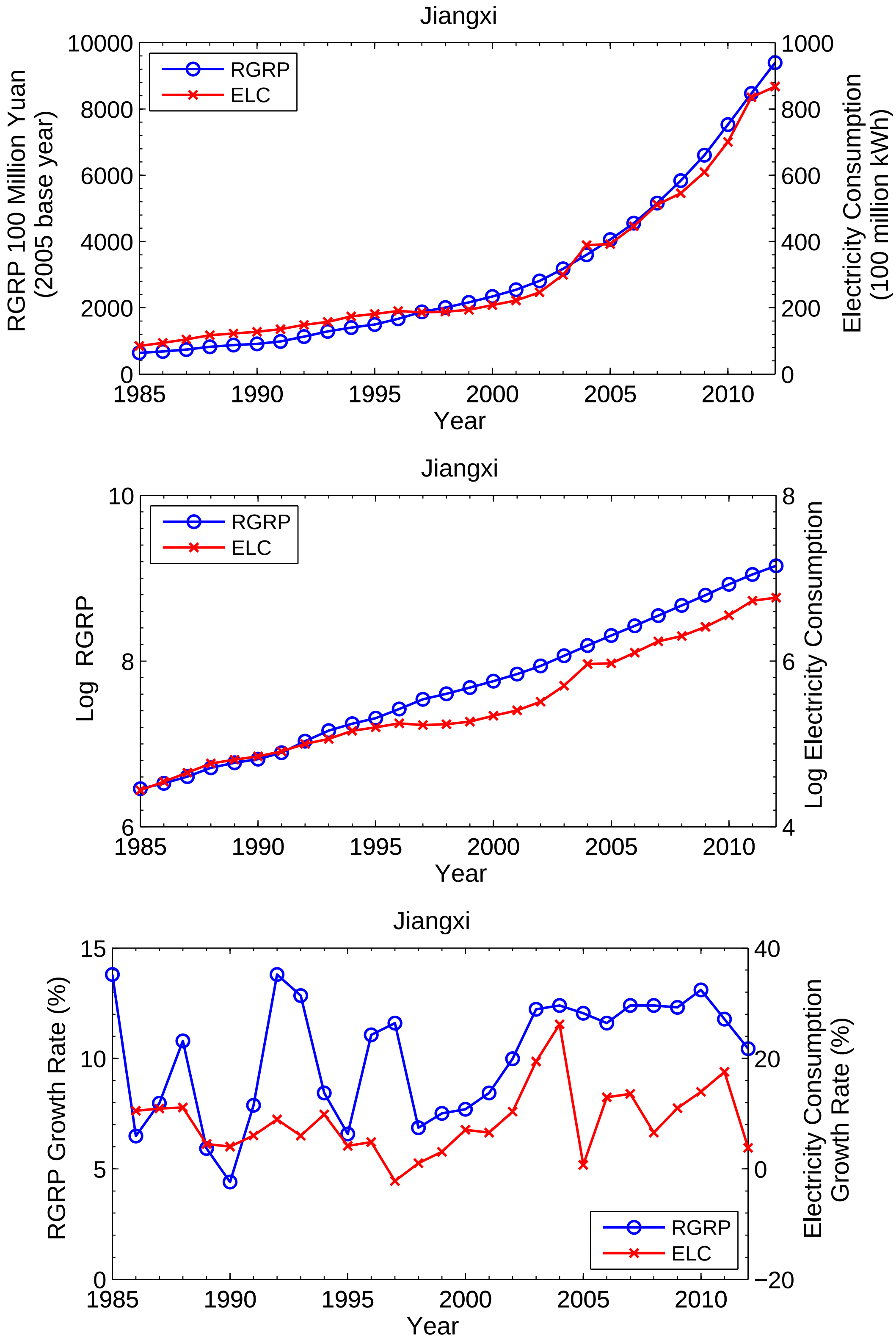

Figure 25: Jiangxi - Figures

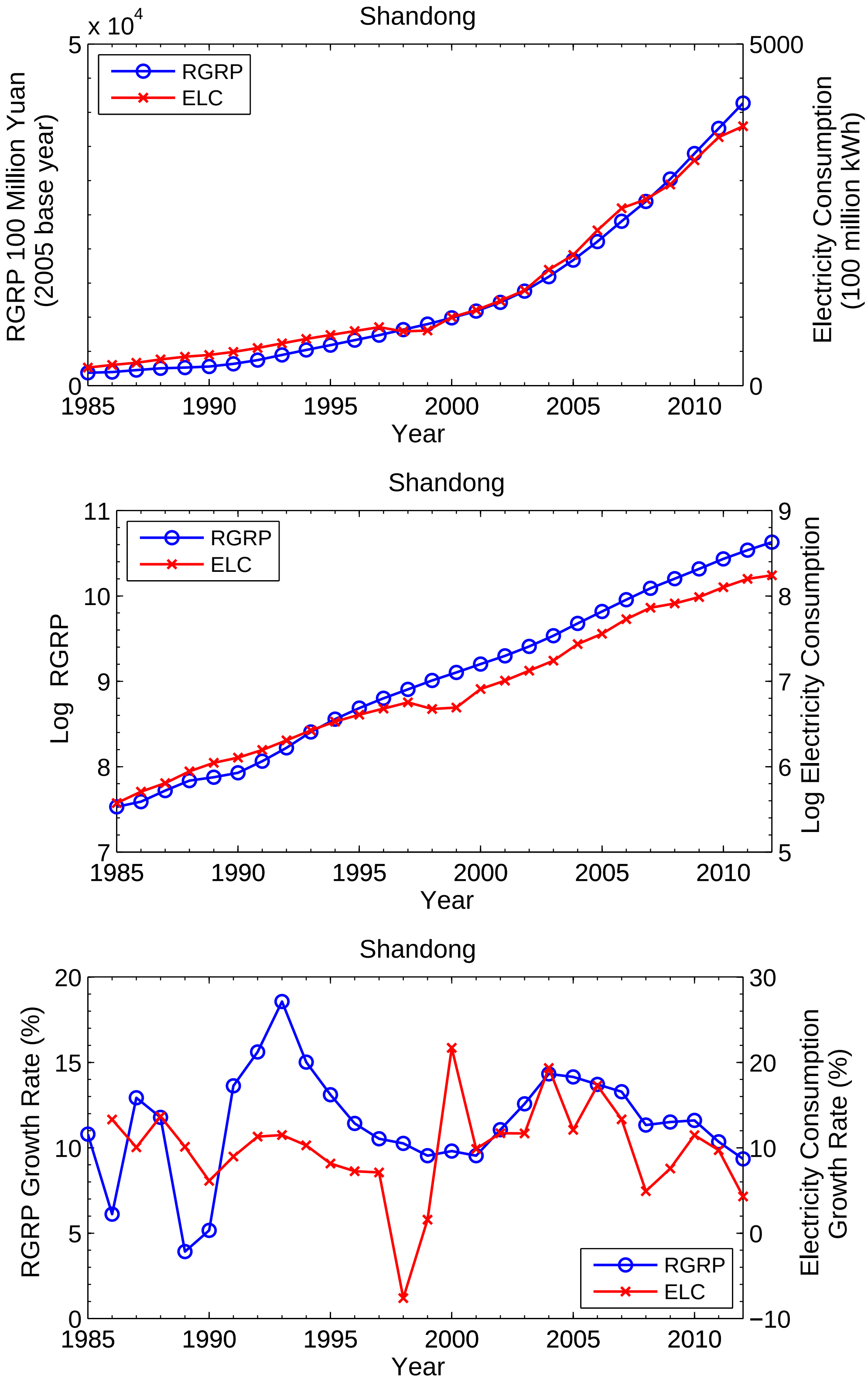

Figure 26: Shandong - Figures

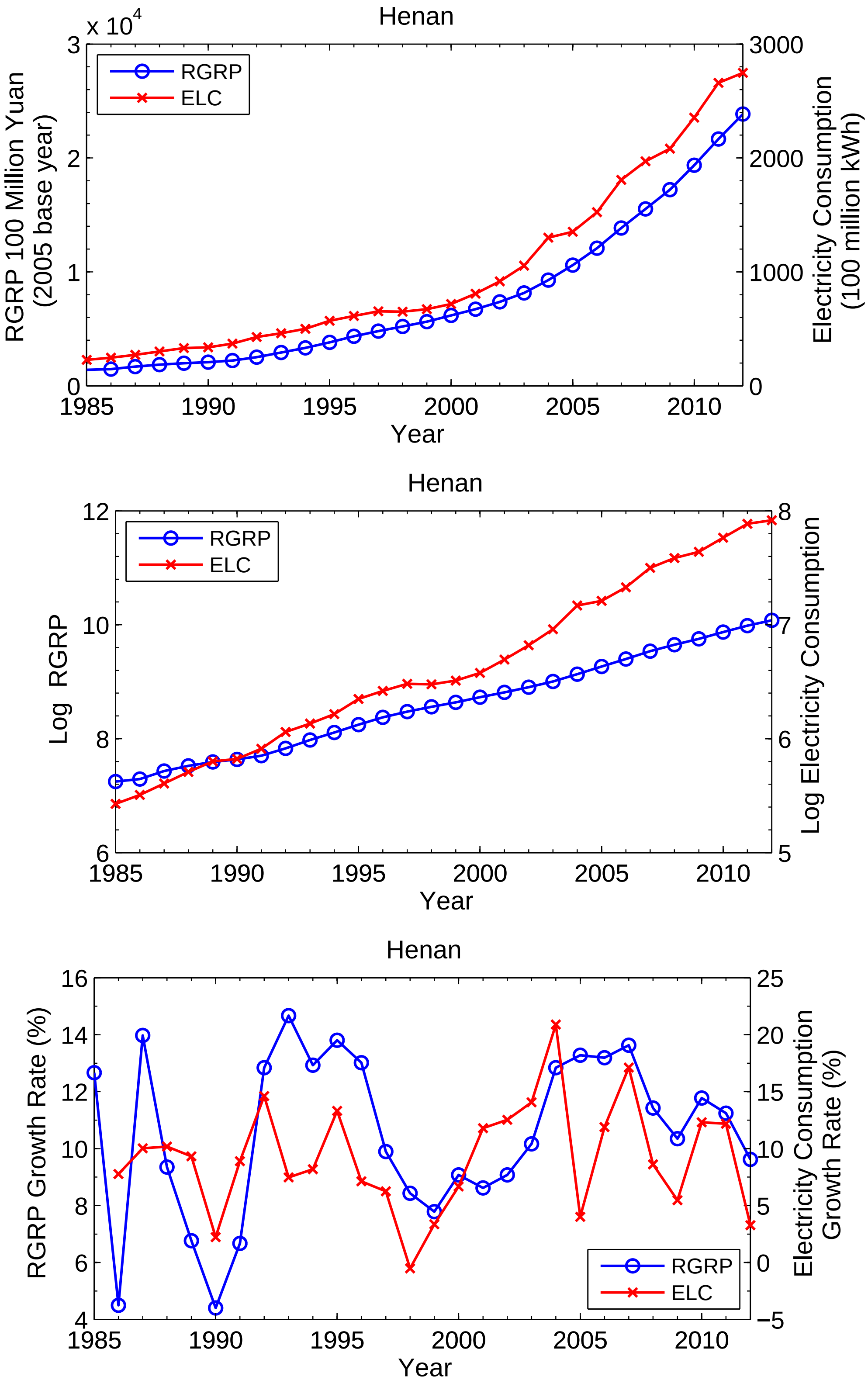

Figure 27: Henan - Figures

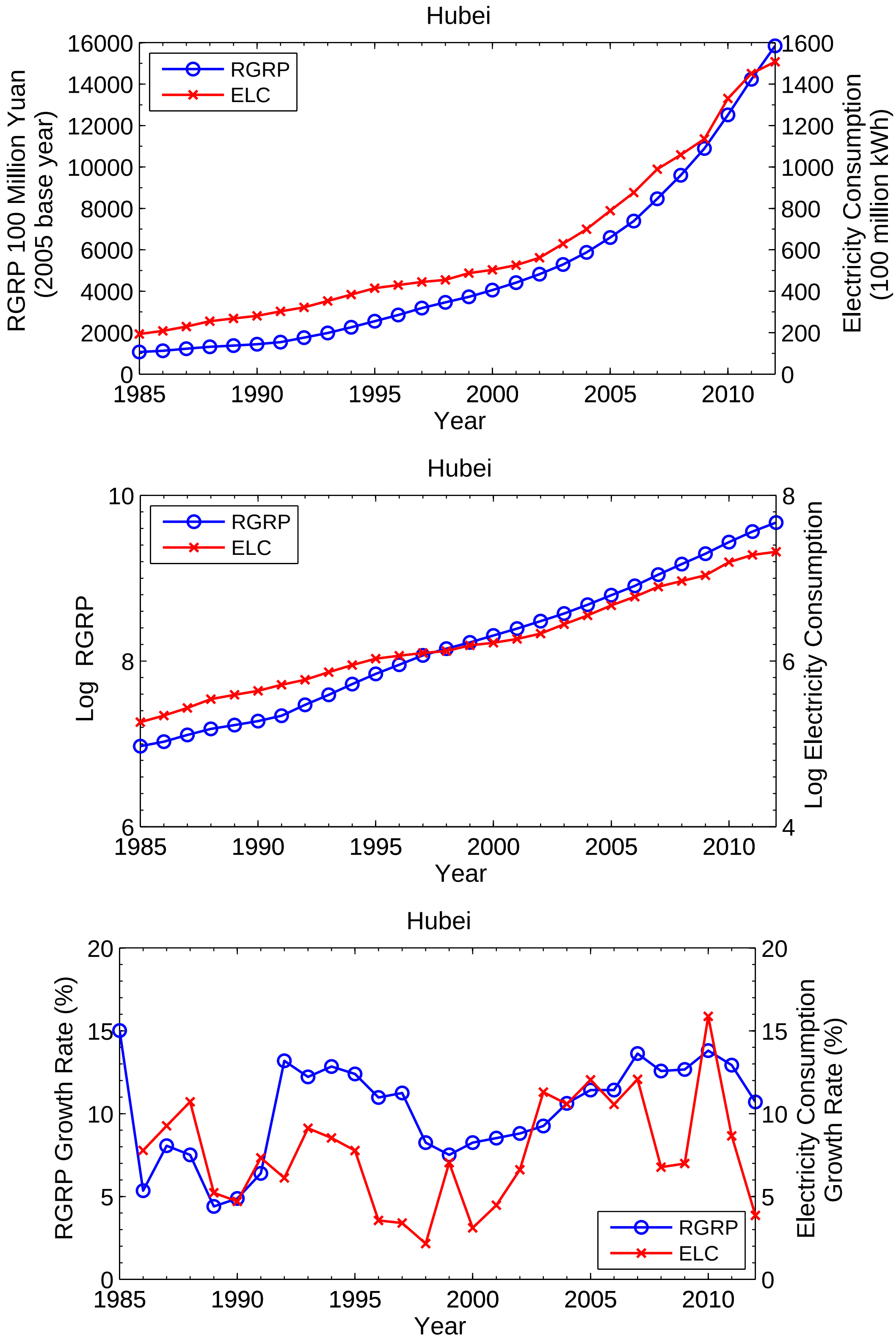

Figure 28: Hubei - Figures

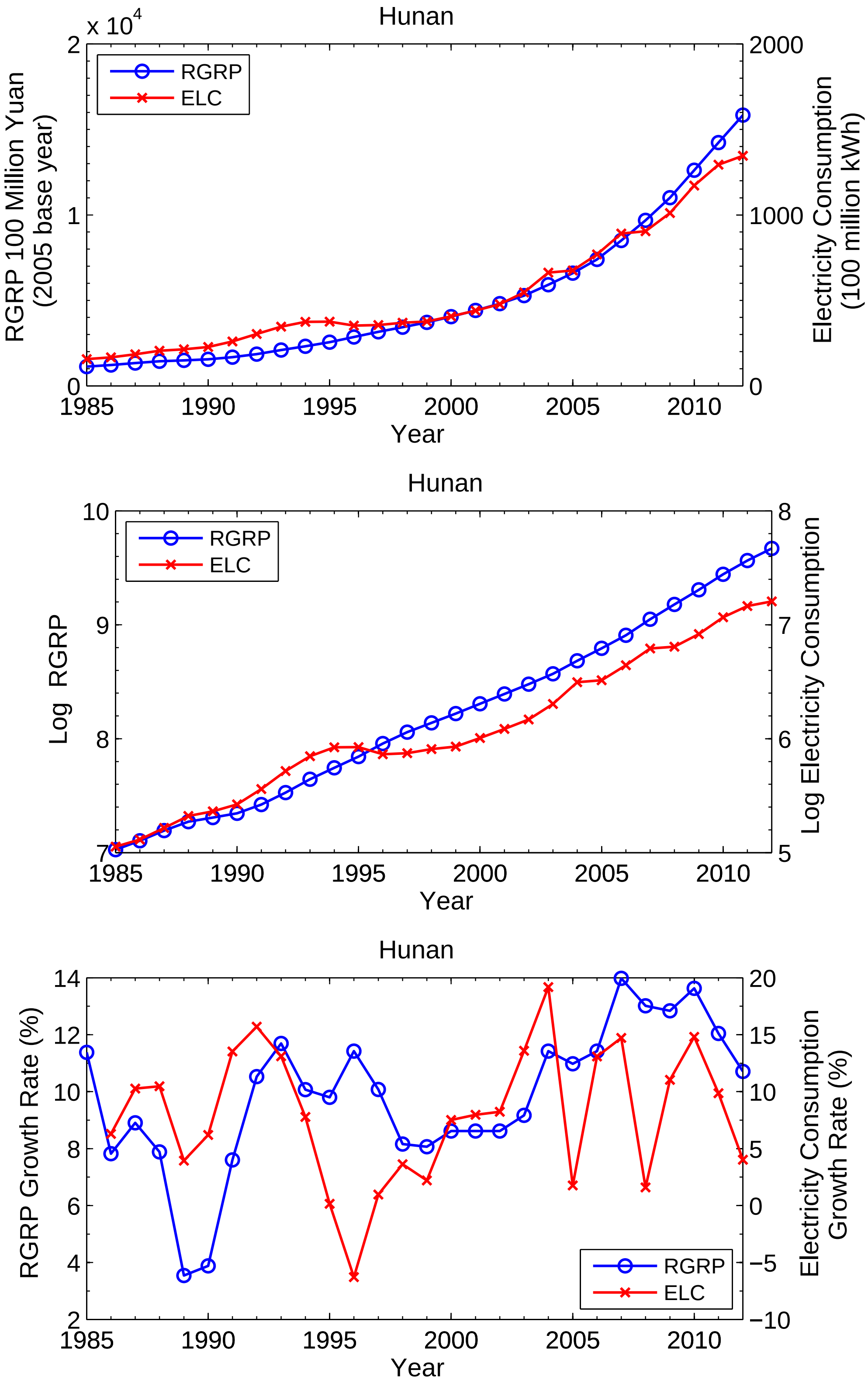

Figure 29: Hunan - Figures

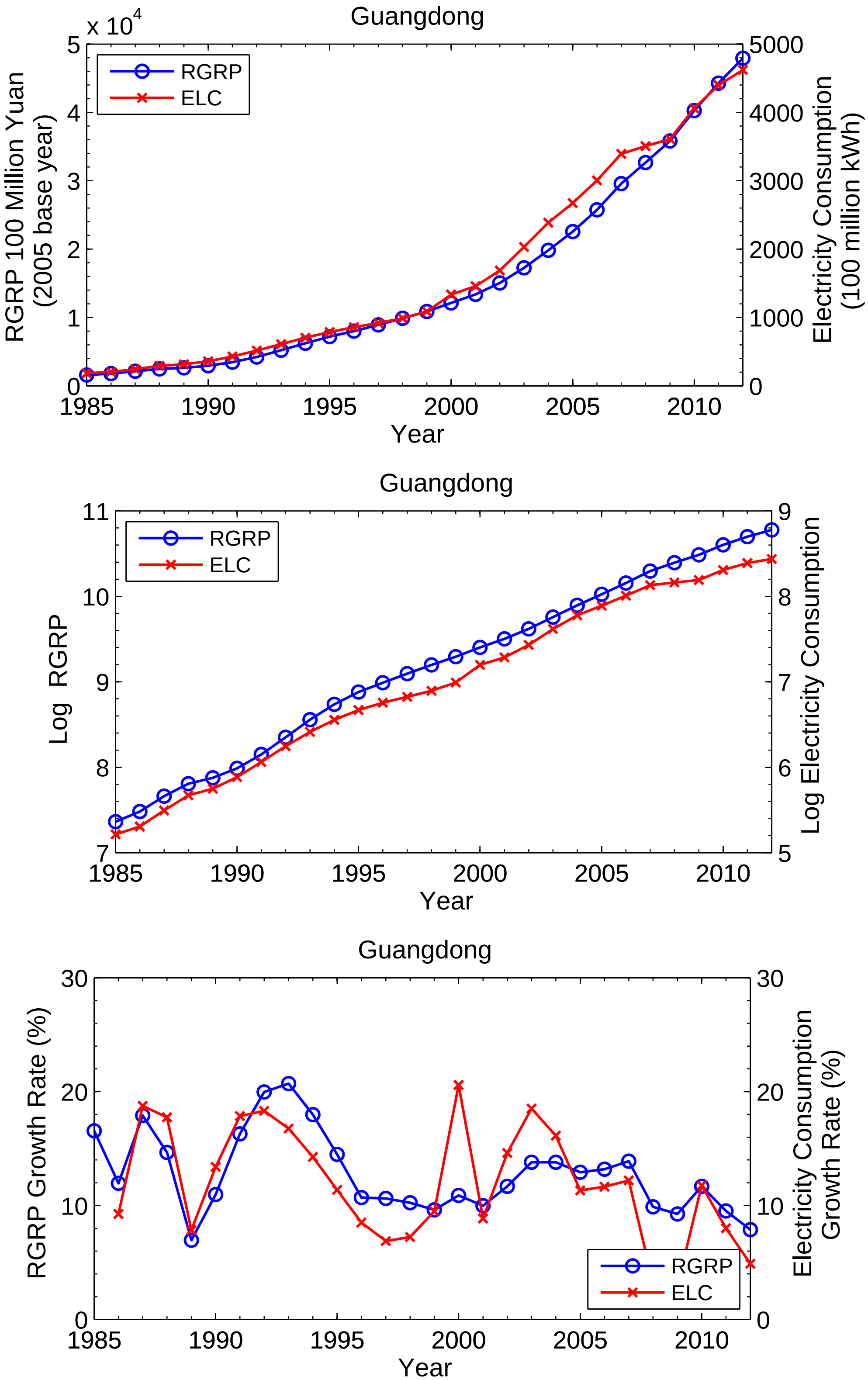

Figure 30: Guangdong - Figures

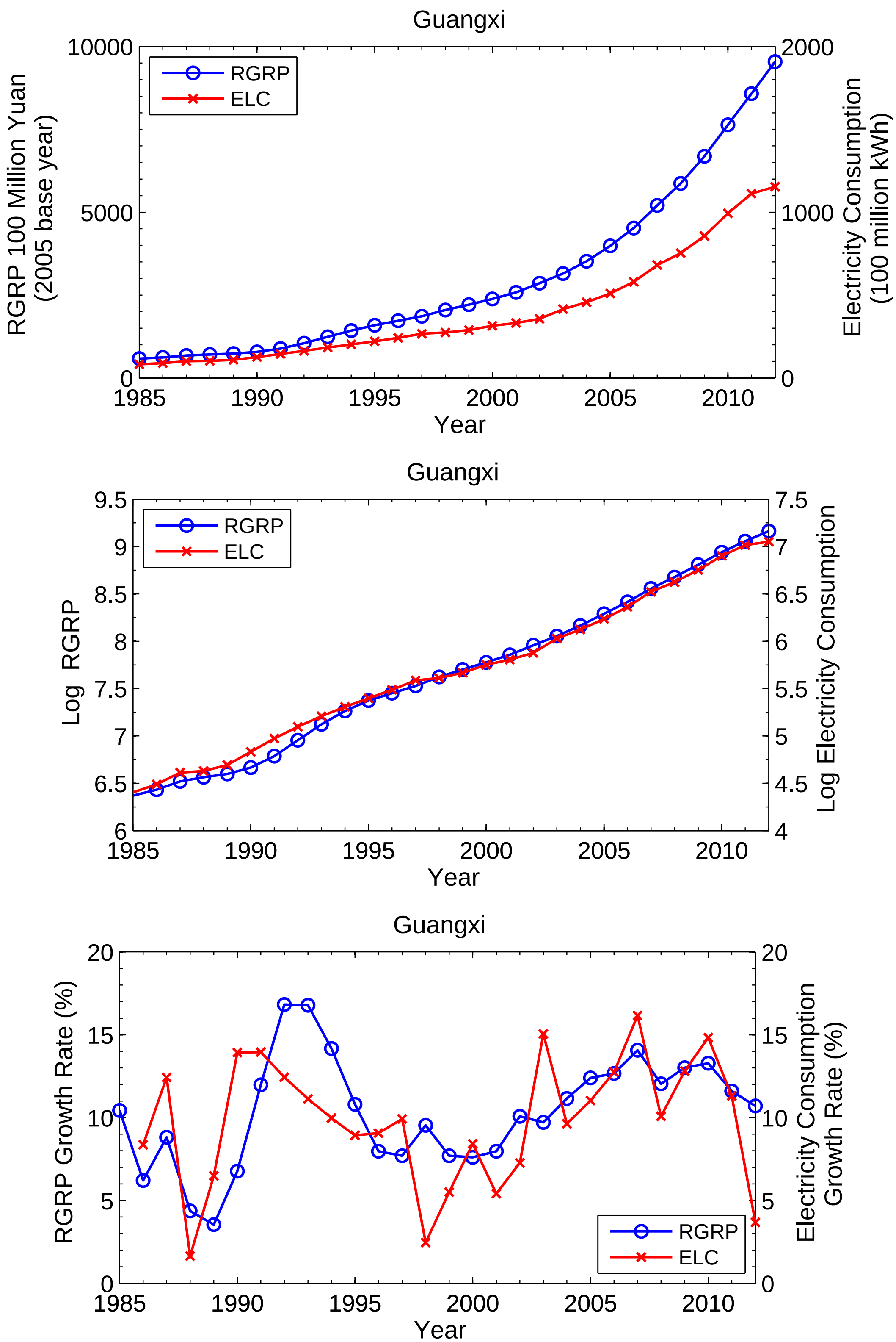

Figure 31: Guangxi - Figures

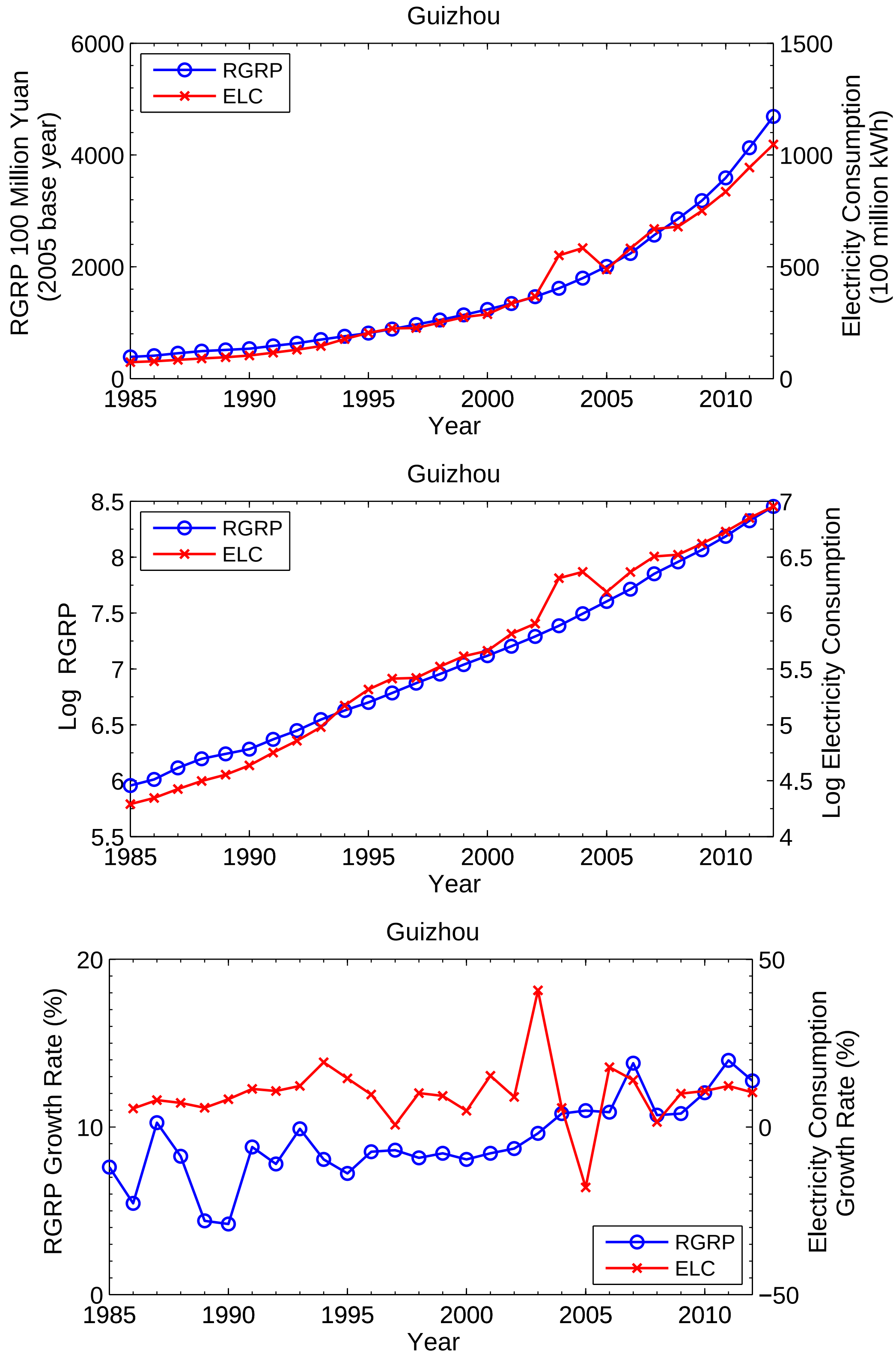

Figure 32: Guizhou - Figures

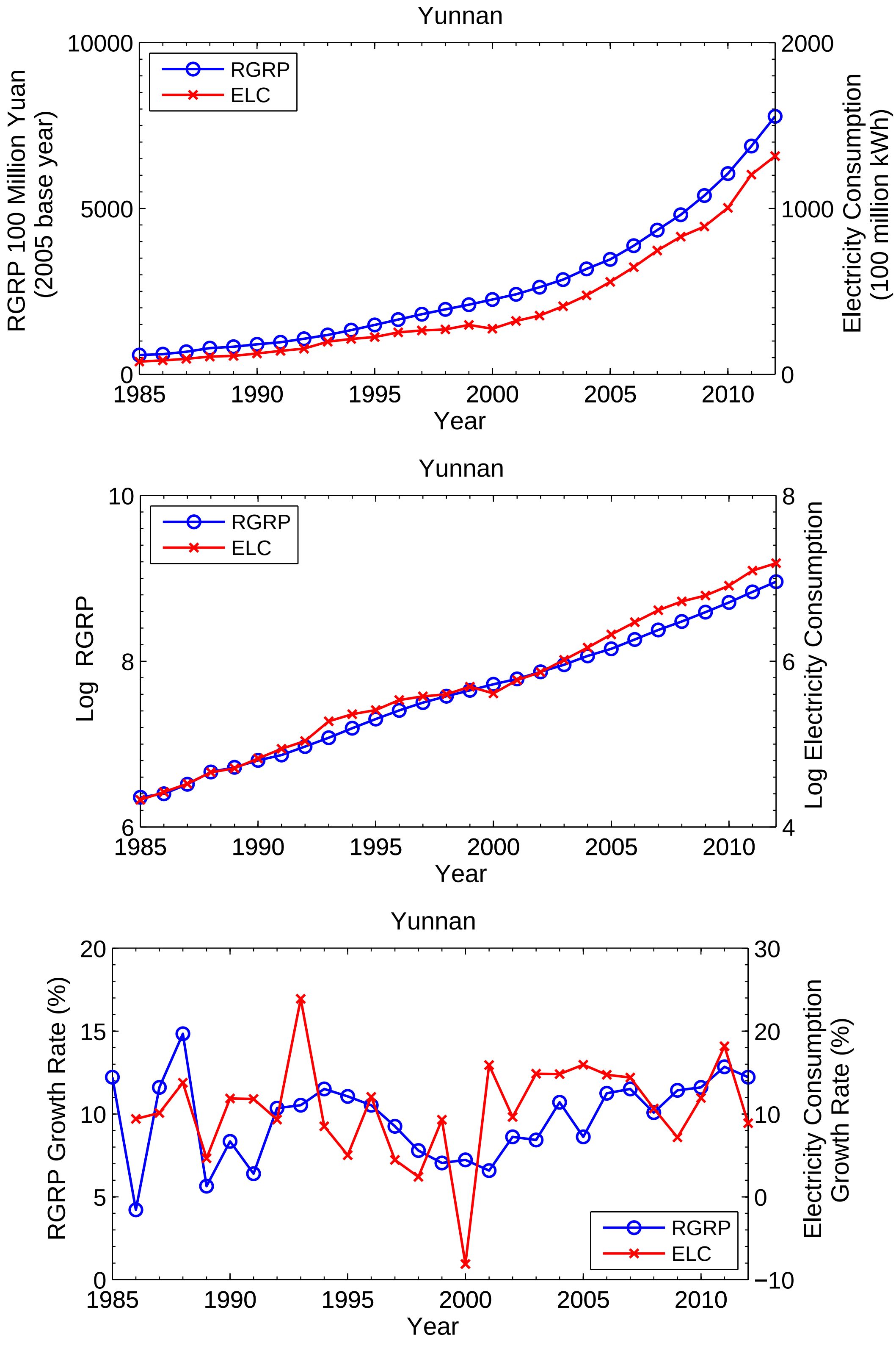

Figure 33: Yunnan - Figures

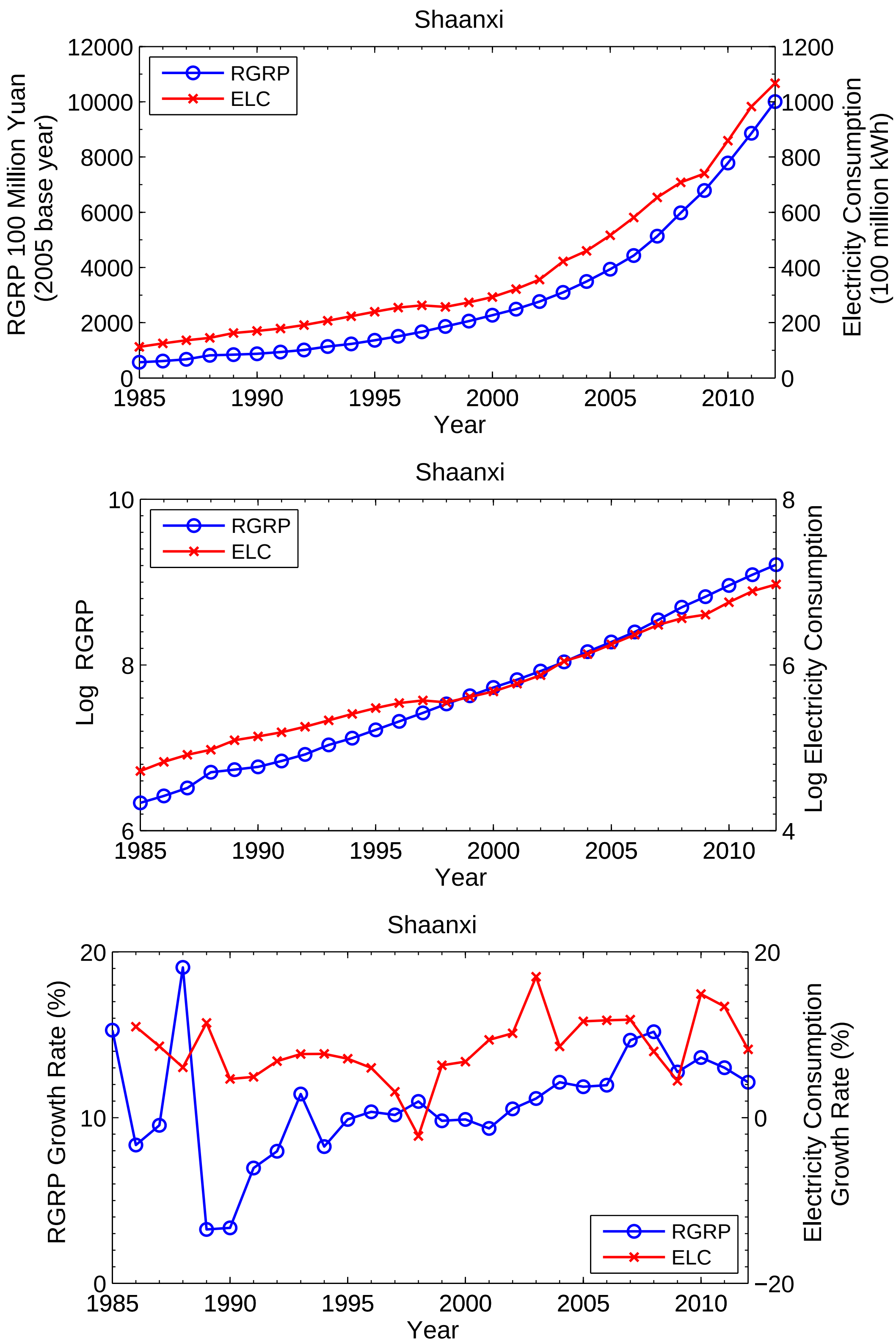

Figure 34: Shaanxi - Figures

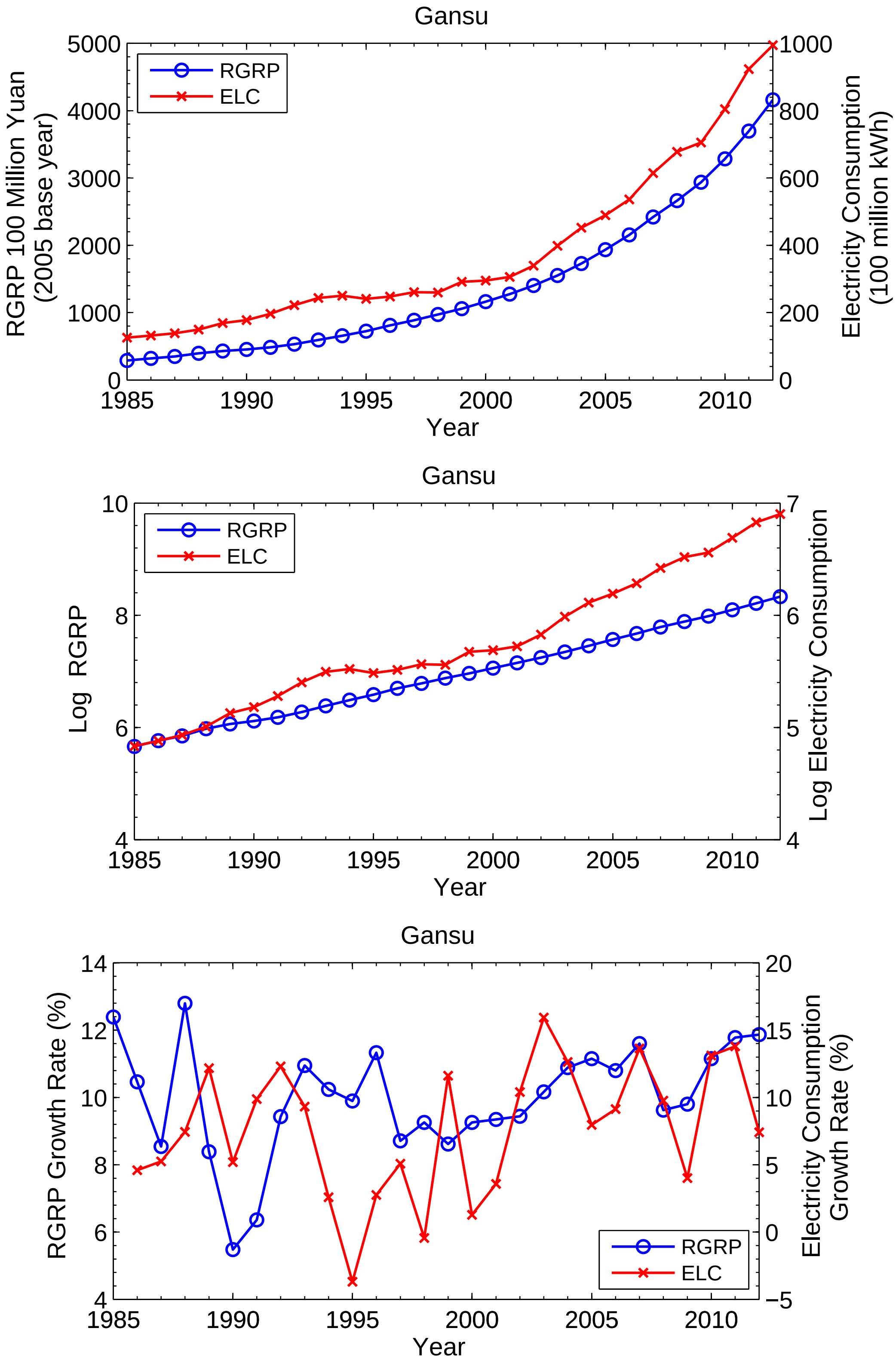

Figure 35: Gansu - Figures

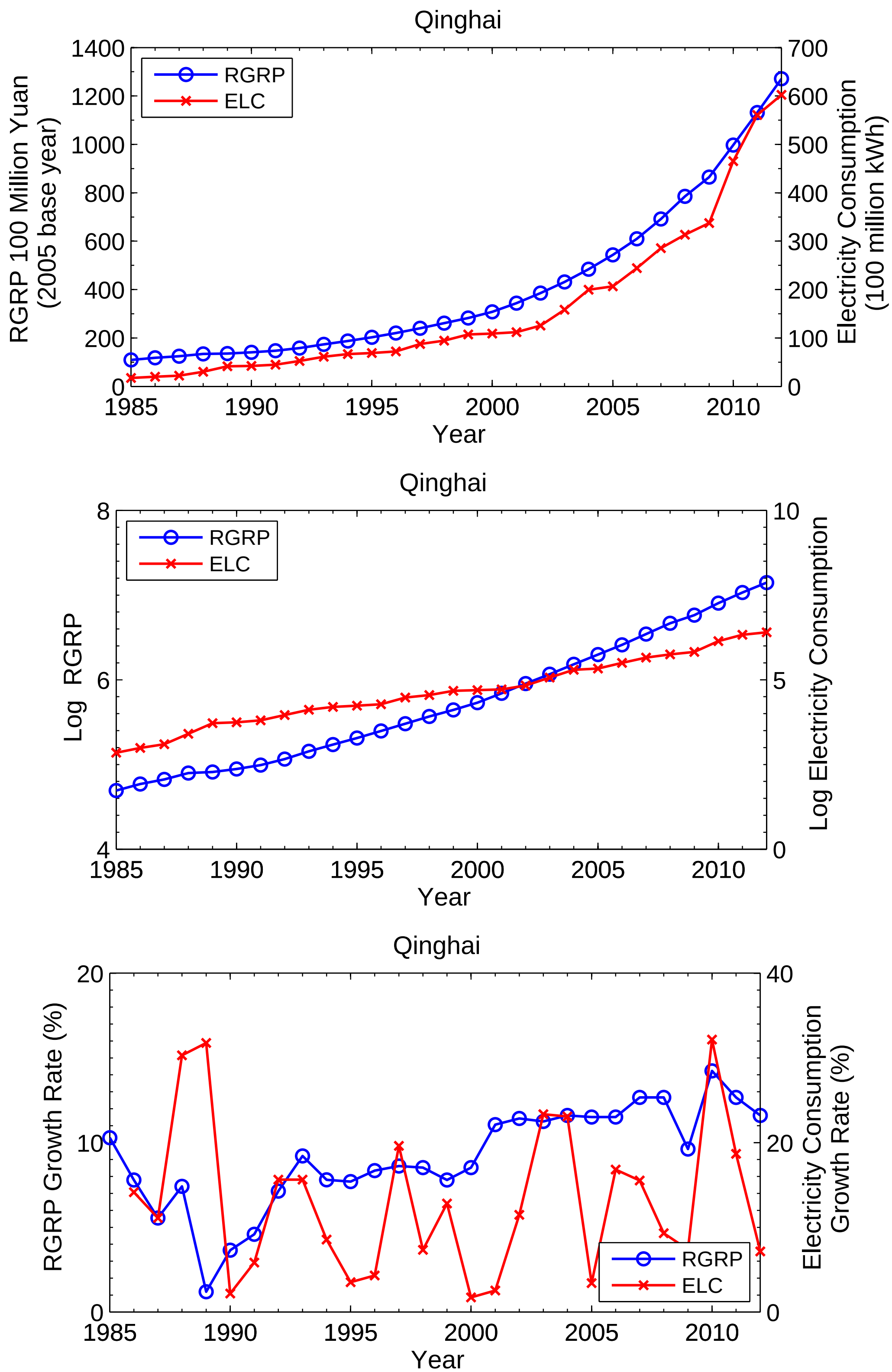

Figure 36: Qinghai - Figures

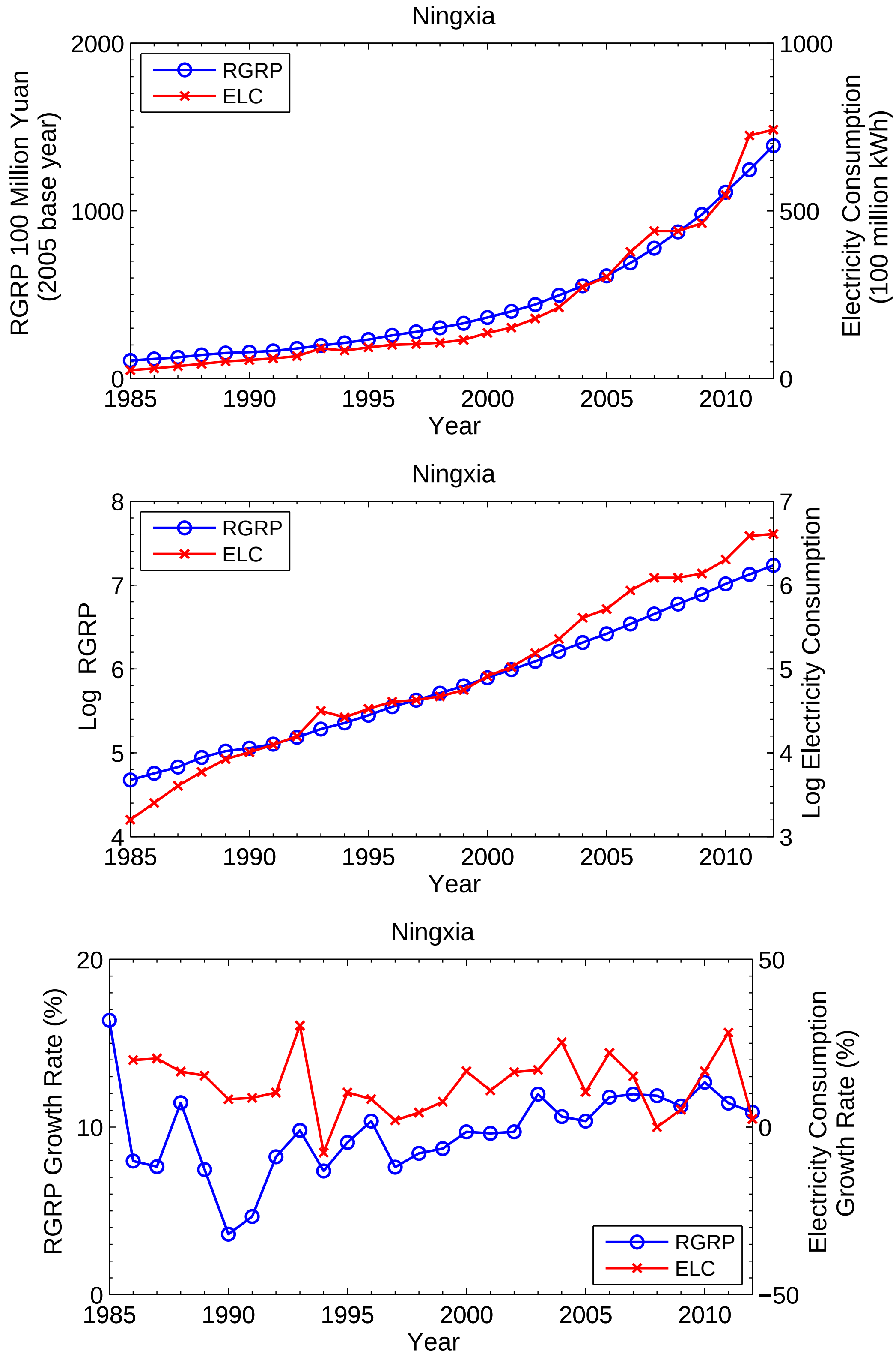

Figure 37: Ningxia - Figures

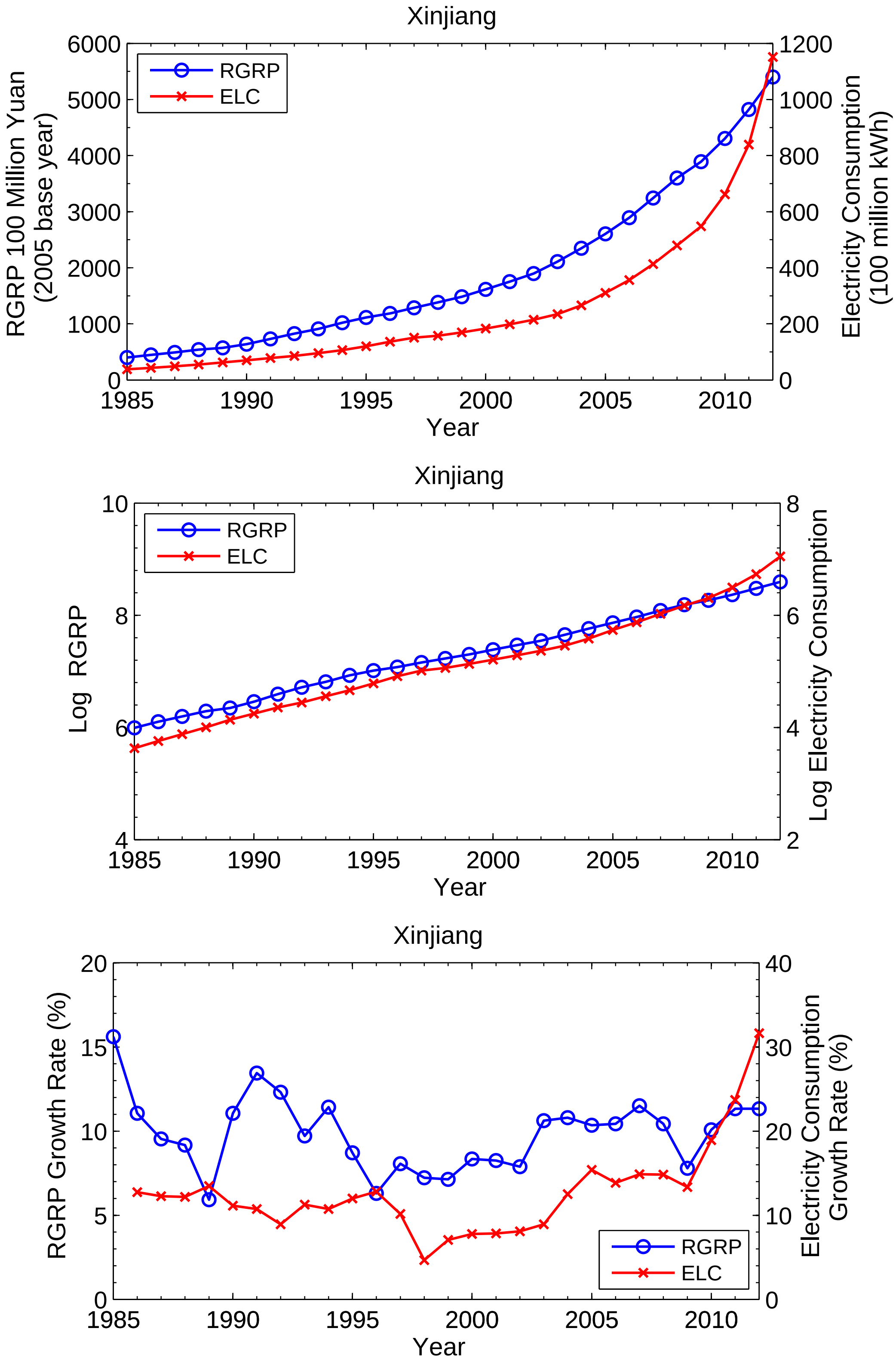

Figure 38: Xinjiang - Figures

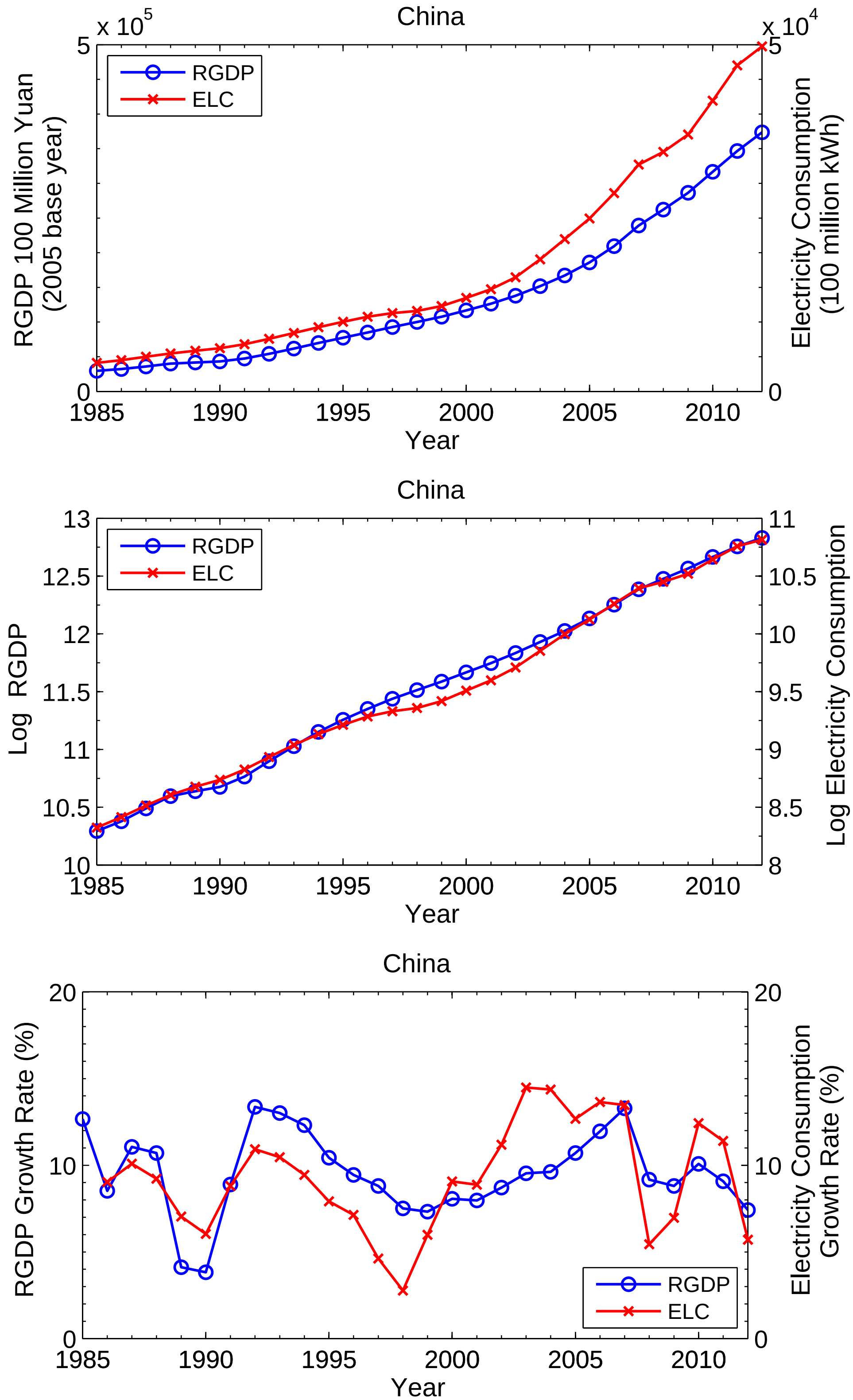

Figure 39: China - Figures

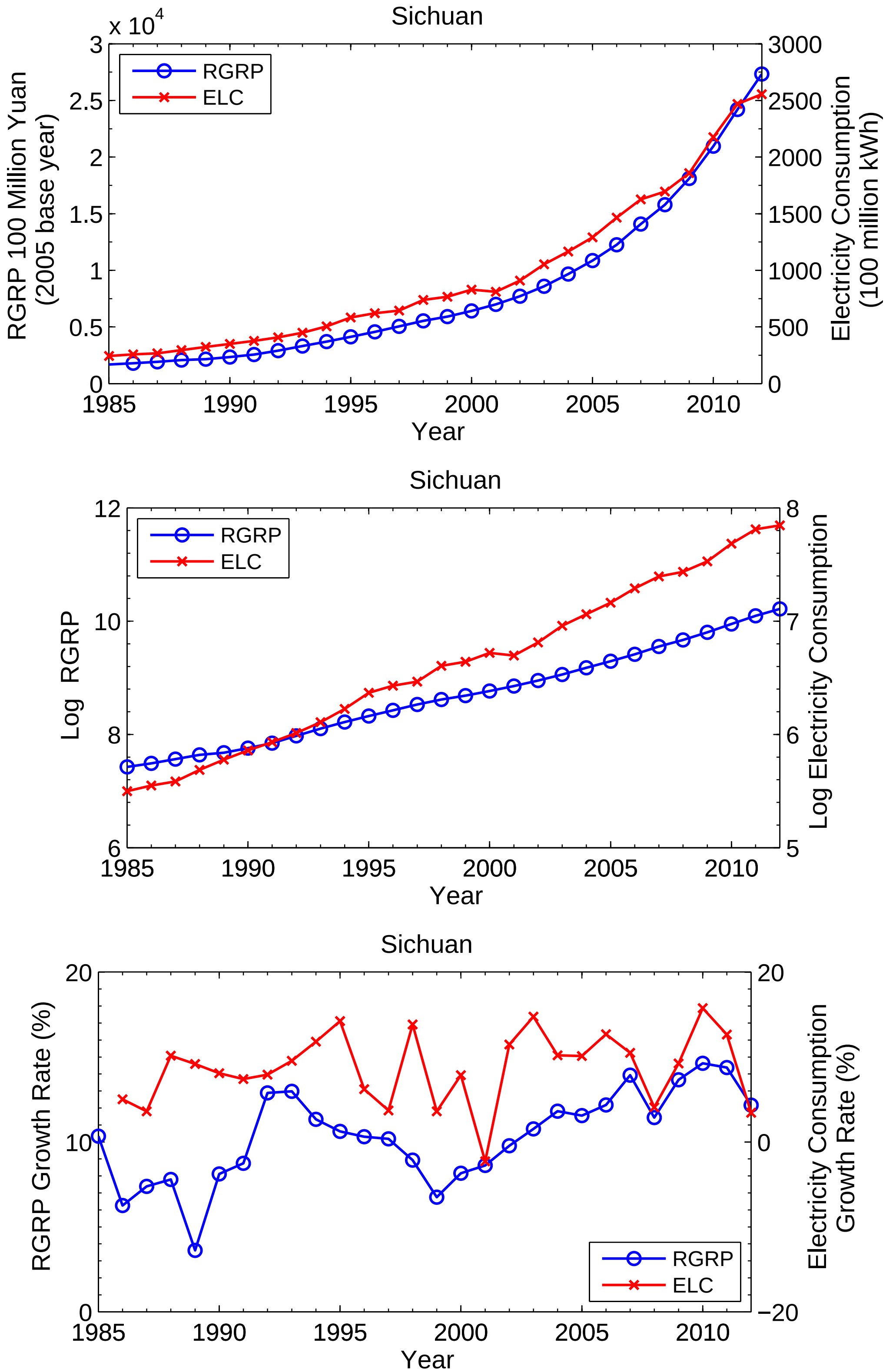

Figure 40: Sichuan - Figures

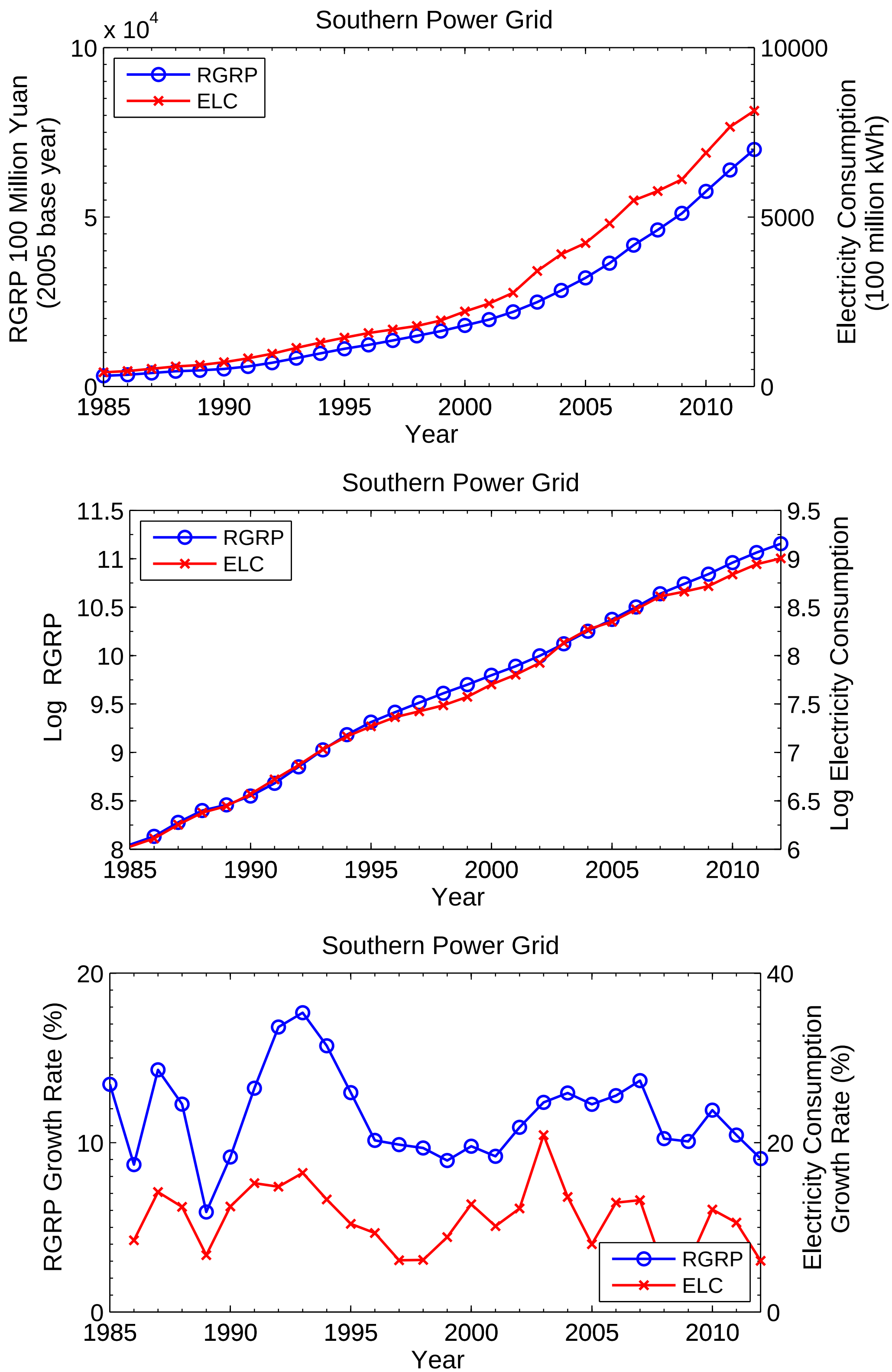

Figure 41: Southern Power Grid - Figures

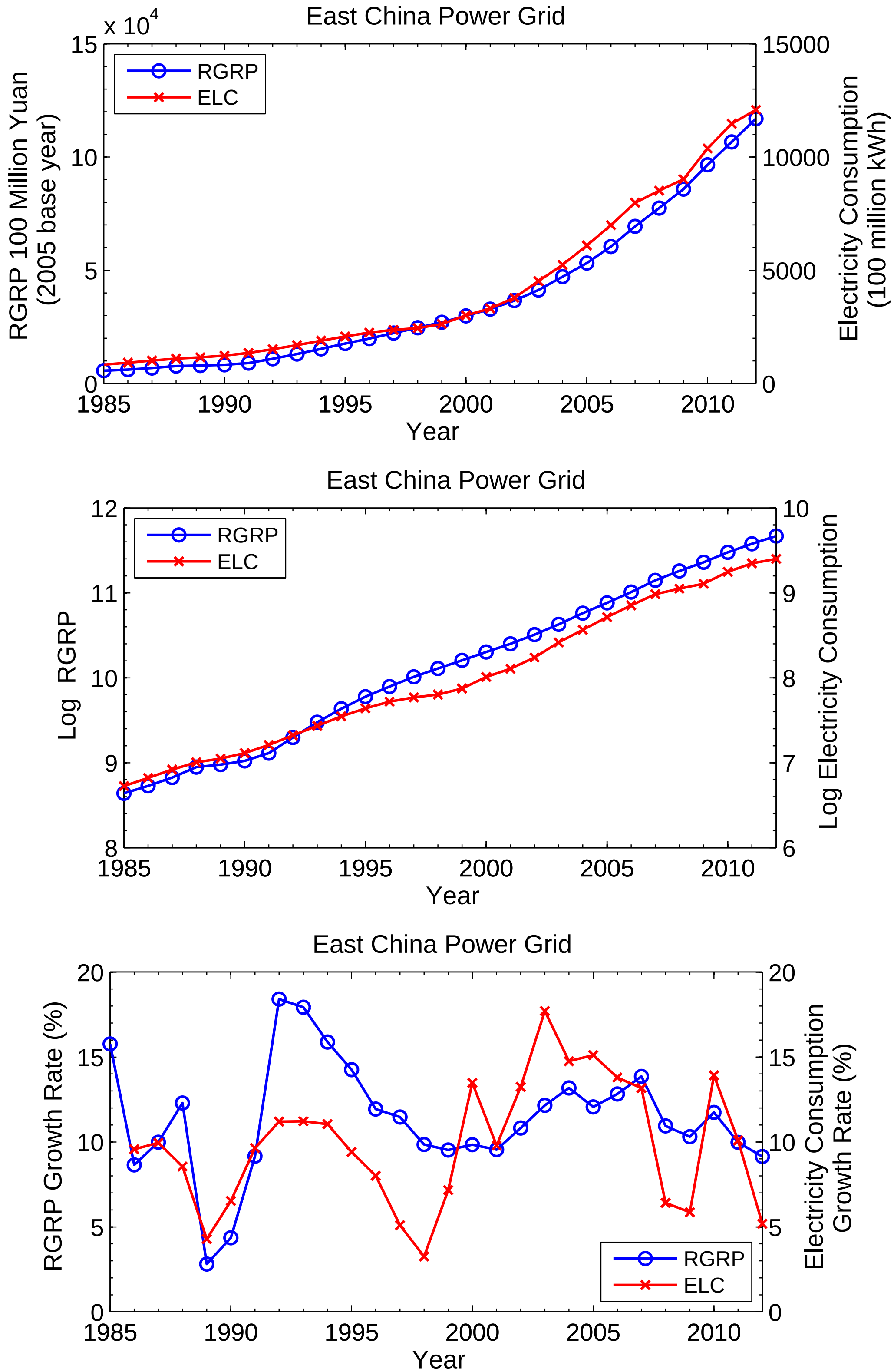

Figure 42: East China Power Grid - Figures

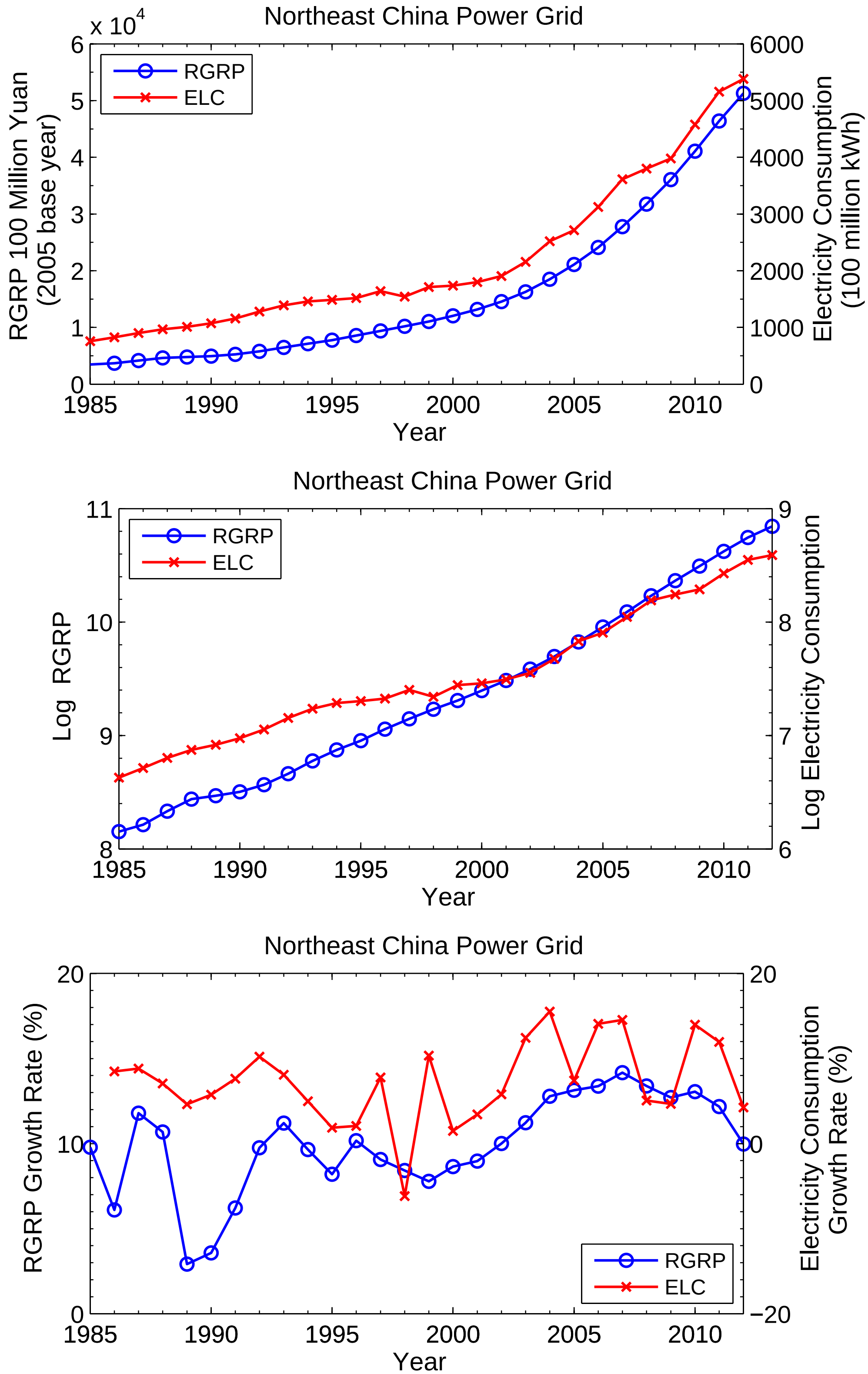

Figure 43: Northeast China Power Grid - Figures

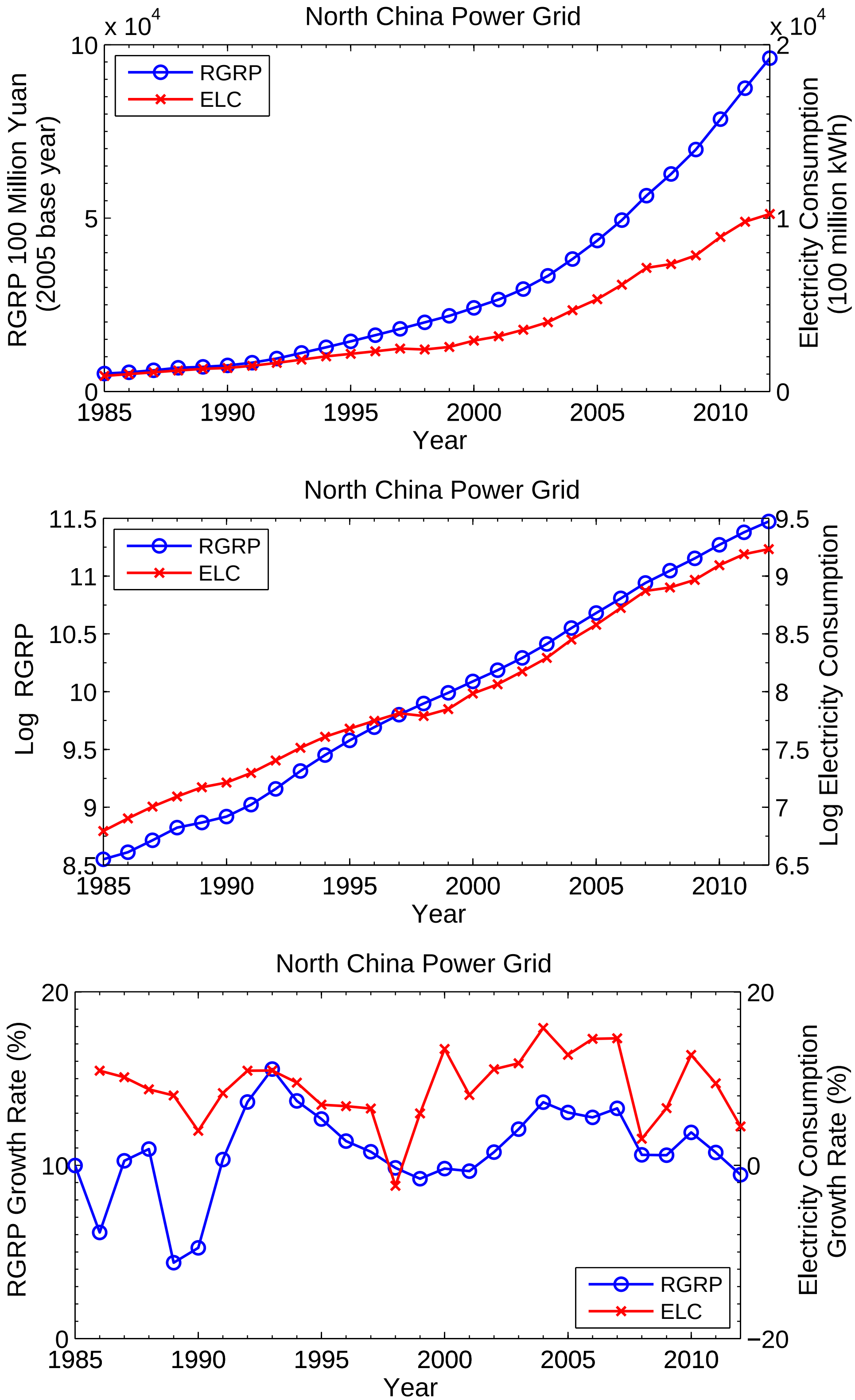

Figure 44: North China Power Grid - Figures

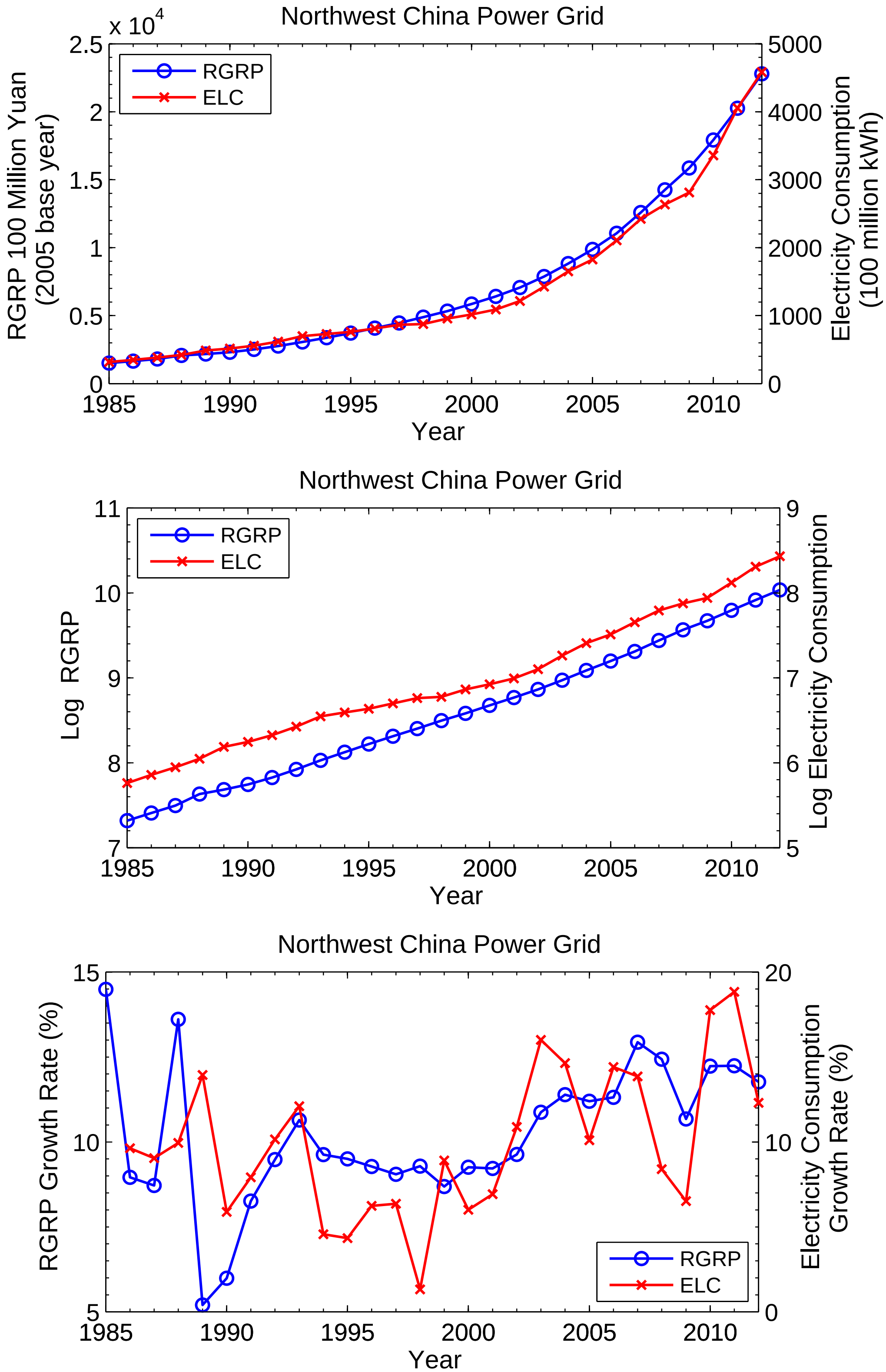

Figure 45: Northwest China Power Grid - Figures

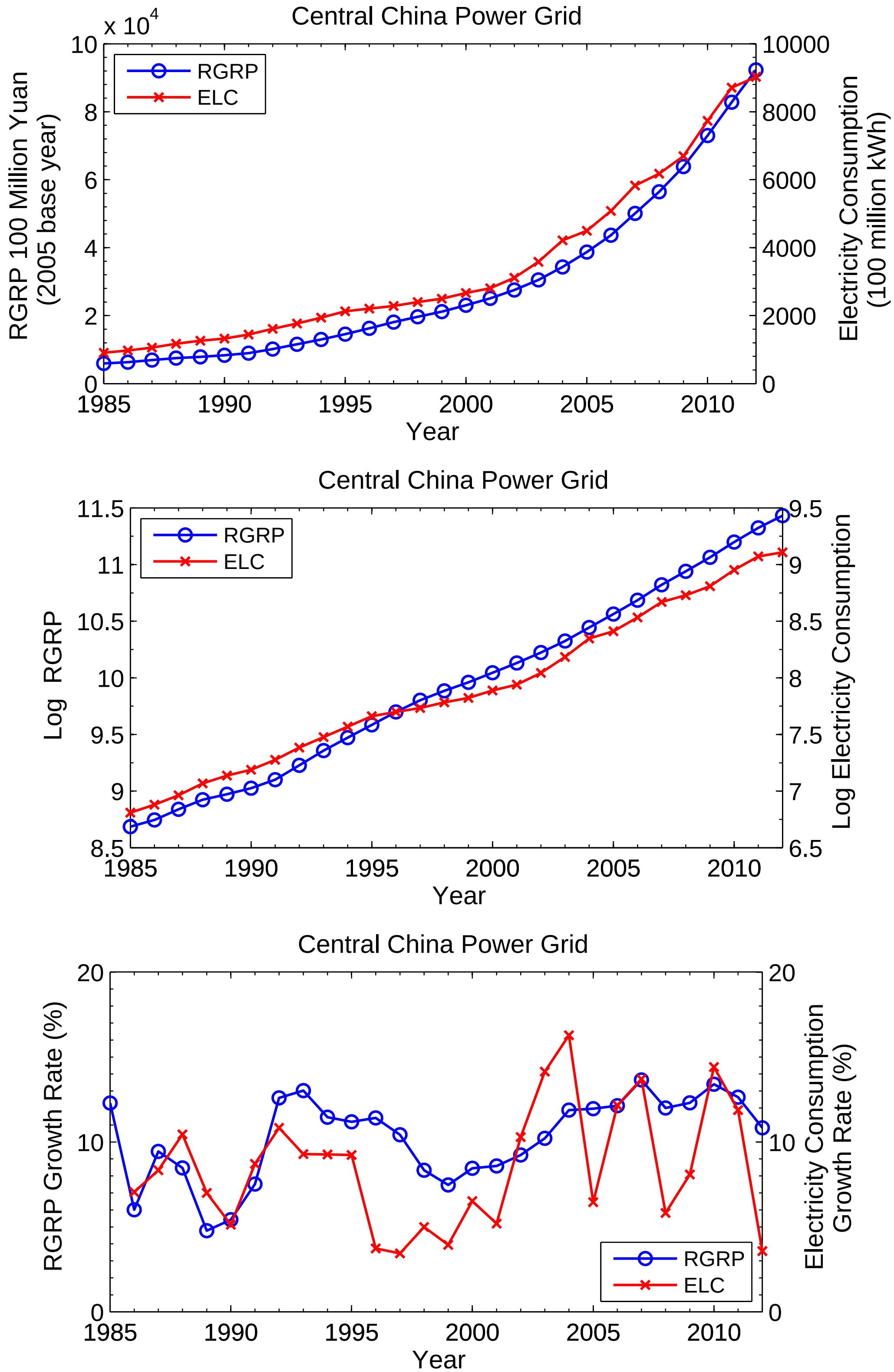

Figure 46: Central China Power Grid - Figures

C VECM results

Province Name: Beijing
Province ID: 101
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1084	13436	4924
	ELC	28	126.2	874.3	402.2
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.27	(0.452)	-2.64	(0.007)***
	ELC	-2.18	(0.502)	-3.61	(0.001)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-2.432	-2.333		
	1	-11.01	-10.71		
	2	-10.78	-10.29		
	3	-10.81	-10.12		
	4	-10.51	-9.630		
Johansen test for co-integration	**No. co-integrating equations**			**Critical values**	
		LL	**Trace**	**10%**	**5%**
	0	135.4	20.1	13.33	15.41
	1	145.2	0.362	2.69	3.76
	2	145.4			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.008	0.080		
		(0.755)	(0.029)**		
	ECT_{t-1}	-0.247	0.024		
		(0.000)***	(0.821)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.893)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 13: Beijing VECM results

Province Name:	Tianjin
Province ID:	102
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	592.8	10607	2980
	ELC	28	95.7	722.5	288.4
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.25	(0.075)*	-1.83	(0.041)**
	ELC	-0.956	(0.950)	-1.91	(0.035)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.3080	-0.2098		
	1	-8.092	-7.798		
	2	-8.437	-7.946		
	3	-8.306	-7.619		
	4	-8.206	-7.323		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	115.4	9.93	13.33	15.41
	1	119.5	1.65	2.69	3.76
	2	120.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.035	0.017		
		(0.013)**	(0.657)		
	ECT_{t-1}	-0.072	0.150		
		(0.091)*	(0.193)		
	ΔRGRP				
	L1	0.759	0.421		
		(0.000)***	(0.169)		
	ΔELC				
	L1	-0.070	0.153		
		(0.431)	(0.524)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.870)			
	2	(0.930)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 14: Tianjin VECM results

Province Name:	Hebei
Province ID:	103
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1343	20654	7114
	ELC	28	243.8	3078	1091
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-4.63	(0.001)***	-3.78	(0.001)***
	ELC	-1.84	(0.686)	-2.16	(0.023)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.4104	0.5086		
	1	-8.219	-7.925		
	2	-8.416	-7.925		
	3	-8.858	-8.171		
	4	-9.333	-8.449		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	124.6	10.8	13.33	15.41
	1	129.1	1.71	2.69	3.76
	2	130.0			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.049	0.009		
		(0.041)**	(0.890)		
	ECT_{t-1}	-0.027	0.149		
		(0.344)	(0.045)**		
	ΔRGRP				
	L1	1.17	1.09		
		(0.000)***	(0.033)**		
	L2	-1.06	-1.55		
		(0.000)***	(0.009)***		
	L3	0.540	-0.275		
		(0.001)***	(0.520)		
	ΔELC				
	L1	0.094	0.184		
		(0.219)	(0.358)		
	L2	-0.040	0.251		
		(0.604)	(0.216)		
	L3	0.000	0.246		
		(0.996)	(0.228)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.002)***		
	ΔELC	(0.658)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.058)*			
	2	(0.067)*			
	3	(0.192)			
	4	(0.678)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 15: Hebei VECM results

Province Name:	Shanxi
Province ID:	104
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	722.8	8539	2972
	ELC	28	163.5	1766	671.5
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.01	(0.131)	-2.75	(0.006)***
	ELC	-2.21	(0.485)	-4.36	(0.000)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.3465	-0.2483		
	1	-7.669	-7.374		
	2	-7.804	-7.313		
	3	-7.681	-6.993		
	4	-7.523	-6.640		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	102.3	17.3	13.33	15.41
	1	108.7	4.47	2.69	3.76
	2	110.9			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.070	0.103		
		(0.000)***	(0.000)***		
	ECT_{t-1}	-0.063	0.043		
		(0.018)**	(0.452)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.918)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 16: Shanxi VECM results

Province Name:	Inner Mongolia
Province ID:	105
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	512.4	10450	2901
	ELC	28	69.7	2017	522.8
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.39	(0.382)	-1.47	(0.079)*
	ELC	-1.38	(0.866)	-1.77	(0.046)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	1.283	1.381		
	1	-6.087	-5.793		
	2	-6.395	-5.904		
	3	-6.099	-5.412		
	4	-5.893	-5.010		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	92.3	7.23	13.33	15.41
	1	95.4	1.10	2.69	3.76
	2	95.9			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.027	-0.002		
		(0.053)*	(0.956)		
	ECT_{t-1}	0.027	0.314		
		(0.549)	(0.018)**		
	ΔRGRP				
	L1	0.682	1.01		
		(0.000)***	(0.011)**		
	ΔELC				
	L1	0.096	0.282		
		(0.142)	(0.146)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.886)			
	2	(0.966)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 17: Inner Mongolia VECM results

Province Name:	Liaoning
Province ID:	106
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1468	18306	6143
	ELC	28	347.9	1900	872.2
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.06	(0.936)	-1.96	(0.034)**
	ELC	-1.36	(0.873)	-1.69	(0.055)*
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-1.153	-1.055		
	1	-8.034	-7.740		
	2	-7.889	-7.398		
	3	-8.547	-7.860		
	4	-8.677	-7.794		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	113.0	18.3	13.33	15.41
	1	119.1	6.15	2.69	3.76
	2	122.1			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.020	0.002		
		(0.157)	(0.950)		
	ECT_{t-1}	-0.031	0.285		
		(0.466)	(0.007)***		
	ΔRGRP				
	L1	1.31	2.36		
		(0.000)***	(0.000)***		
	L2	-1.10	-2.33		
		(0.000)***	(0.000)***		
	L3	0.423	1.83		
		(0.056)*	(0.001)***		
	ΔELC				
	L1	-0.082	0.007		
		(0.394)	(0.978)		
	L2	0.050	0.326		
		(0.604)	(0.175)		
	L3	0.037	0.133		
		(0.672)	(0.540)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.001)***		
	ΔELC	(0.649)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.407)			
	2	(0.157)			
	3	(0.802)			
	4	(0.961)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 18: Liaoning VECM results

Province Name:	Jilin
Province ID:	107
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	631.0	8904	2840
	ELC	28	139.9	637.0	324.6
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-0.836	(0.963)	-3.29	(0.002)***
	ELC	-1.66	(0.770)	-4.02	(0.000)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.6558	-0.5576		
	1	-7.844	-7.549		
	2	-7.574	-7.083		
	3	-7.565	-6.878		
	4	-7.521	-6.638		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	96.3	12.7	13.33	15.41
	1	101.0	3.40	2.69	3.76
	2	102.7			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.068	0.081		
		(0.000)***	(0.000)***		
	ECT_{t-1}	-0.073	0.061		
		(0.029)**	(0.167)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.179)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 19: Jilin VECM results

Province Name: Heilongjiang
Province ID: 108
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1197	11803	4164
	ELC	28	199.2	827.9	464.9
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.86	(0.175)	-1.24	(0.115)
	ELC	-2.28	(0.444)	-2.37	(0.014)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.5149	-0.4167		
	1	-9.525	-9.231		
	2	-9.938	-9.447		
	3	-9.859	-9.172		
	4	-9.583	-8.699		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	124.4	16.8	13.33	15.41
	1	131.0	3.76	2.69	3.76
	2	132.8			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.014	-0.003		
		(0.212)	(0.957)		
	ECT_{t-1}	0.028	0.148		
		(0.038)**	(0.015)**		
	ΔRGRP				
	L1	0.490	-1.50		
		(0.001)***	(0.023)**		
	ΔELC				
	L1	-0.046	0.045		
		(0.282)	(0.814)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.033)**			
	2	(0.974)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 20: Heilongjiang VECM results

Province Name:	Shanghai
Province ID:	109
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1399	17950	6466
	ELC	28	203.8	1353	629.7
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.83	(0.185)	-3.63	(0.001)***
	ELC	-2.05	(0.576)	-2.55	(0.011)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-1.272	-1.174		
	1	-8.503	-8.209		
	2	-8.625	-8.134		
	3	-8.451	-7.763		
	4	-9.099	-8.215		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	117.5	19.5	13.33	15.41
	1	126.2	2.07	2.69	3.76
	2	127.2			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.026	0.009		
		(0.319)	(0.806)		
	ECT_{t-1}	-0.121	0.359		
		(0.283)	(0.019)**		
	ΔRGRP				
	L1	0.501	0.013		
		(0.041)**	(0.968)		
	L2	-0.329	-1.08		
		(0.214)	(0.003)***		
	L3	0.421	0.310		
		(0.039)**	(0.265)		
	ΔELC				
	L1	0.212	0.306		
		(0.255)	(0.229)		
	L2	0.210	0.610		
		(0.270)	(0.019)**		
	L3	-0.149	0.725		
		(0.488)	(0.013)**		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.016)**		
	ΔELC	(0.422)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.373)			
	2	(0.540)			
	3	(0.637)			
	4	(0.988)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 21: Shanghai VECM results

Province Name:	Jiangsu
Province ID:	110
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1939	41624	13289
	ELC	28	277.4	4581	1484
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.25	(0.075)*	-3.78	(0.001)***
	ELC	-2.06	(0.570)	-1.76	(0.046)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	1.013	1.111		
	1	-6.924	-6.629		
	2	-7.207	-6.716		
	3	-6.987	-6.300		
	4	-6.931	-6.048		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	102.6	5.35	13.33	15.41
	1	105.2	0.161	2.69	3.76
	2	105.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.086	0.022		
		(0.003)***	(0.452)		
	ECT_{t-1}	-0.028	0.111		
		(0.620)	(0.058)*		
	ΔRGRP				
	L1	0.151	-0.174		
		(0.481)	(0.425)		
	ΔELC				
	L1	0.170	0.721		
		(0.289)	(0.000)***		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.701)			
	2	(0.312)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 22: Jiangsu VECM results

Province Name: Zhejiang
Province ID: 111
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1445	26906	9233
	ELC	28	147.2	3211	1071
ADF test					
			Levels	**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.98	(0.138)	-2.46	(0.012)**
	ELC	-2.21	(0.483)	-1.61	(0.062)*
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.5303	0.6285		
	1	-7.040	-6.745		
	2	-7.586	-7.096		
	3	-7.453	-6.766		
	4	-7.548	-6.664		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	107.7	5.14	13.33	15.41
	1	110.1	0.353	2.69	3.76
	2	110.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.055	0.017		
		(0.129)	(0.706)		
	ECT_{t-1}	-0.039	0.125		
		(0.638)	(0.222)		
	ΔRGRP				
	L1	0.502	-0.217		
		(0.026)**	(0.438)		
	ΔELC				
	L1	0.101	0.670		
		(0.611)	(0.007)***		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.380)			
	2	(0.192)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 23: Zhejiang VECM results

Province Name: Anhui
Province ID: 112
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	925.1	12308	4022
	ELC	28	127.5	1361	462.9
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.70	(0.238)	-2.09	(0.025)**
	ELC	-1.26	(0.898)	-1.57	(0.066)*
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.6777	0.7759		
	1	-7.495	-7.201		
	2	-8.045	-7.554		
	3	-7.808	-7.121		
	4	-7.947	-7.063		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	111.1	9.04	13.33	15.41
	1	113.6	3.94	2.69	3.76
	2	115.6			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.014	-0.008		
		(0.638)	(0.730)		
	ECT_{t-1}	0.017	0.028		
		(0.312)	(0.040)**		
	ΔRGRP				
	L1	0.371	-0.209		
		(0.065)*	(0.204)		
	ΔELC				
	L1	0.158	0.683		
		(0.367)	(0.000)***		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.575)			
	2	(0.193)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 24: Anhui VECM results

Province Name: Fujian
Province ID: 113
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	726.8	15000	4792
	ELC	28	77.2	1580	527.5
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-4.46	(0.002)***	-3.16	(0.003)***
	ELC	-2.60	(0.279)	-2.62	(0.009)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.1549	-0.0567		
	1	-8.080	-7.785		
	2	-8.785	-8.294		
	3	-9.213	-8.526		
	4	-10.07	-9.189		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	130.3	17.1	13.33	15.41
	1	138.8	0.123	2.69	3.76
	2	138.9			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.066	0.037		
		(0.006)***	(0.623)		
	ECT_{t-1}	-0.112	0.204		
		(0.030)**	(0.200)		
	ΔRGRP				
	L1	1.46	0.517		
		(0.000)***	(0.291)		
	L2	-1.20	-0.303		
		(0.000)***	(0.647)		
	L3	0.475	-0.495		
		(0.001)***	(0.239)		
	ΔELC				
	L1	-0.244	0.415		
		(0.005)***	(0.121)		
	L2	0.167	-0.317		
		(0.111)	(0.326)		
	L3	-0.091	0.580		
		(0.340)	(0.047)**		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.158)		
	ΔELC	(0.029)**	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.060)*			
	2	(0.634)			
	3	(0.881)			
	4	(0.763)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 25: Fujian VECM results

Province Name:	Jiangxi
Province ID:	114
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	707.0	9031	3021
	ELC	28	84.7	867.7	302.8
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-0.232	(0.991)	-1.41	(0.087)*
	ELC	-1.18	(0.915)	-1.99	(0.030)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.5424	0.6406		
	1	-7.406	-7.111		
	2	-7.210	-6.719		
	3	-7.633	-6.946		
	4	-7.389	-6.506		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	102.4	5.97	13.33	15.41
	1	104.1	2.60	2.69	3.76
	2	105.4			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.043	-0.007		
		(0.013)**	(0.883)		
	ECT_{t-1}	0.027	0.166		
		(0.458)	(0.090)*		
	ΔRGRP				
	L1	0.406	0.259		
		(0.035)**	(0.618)		
	ΔELC				
	L1	0.087	0.281		
		(0.262)	(0.181)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.555)			
	2	(0.030)**			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 26: Jiangxi VECM results

Province Name:	Shandong
Province ID:	115
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	2098	40389	13039
	ELC	28	263.4	3795	1360
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.21	(0.083)*	-3.44	(0.001)***
	ELC	-2.02	(0.590)	-3.38	(0.001)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.6445	0.7427		
	1	-6.875	-6.581		
	2	-7.030	-6.539		
	3	-7.028	-6.341		
	4	-6.843	-5.959		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	98.3	4.84	13.33	15.41
	1	100.6	0.412	2.69	3.76
	2	100.8			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.125	0.071		
		(0.000)***	(0.005)***		
	ECT_{t-1}	-0.062	0.110		
		(0.183)	(0.224)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.601)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 27: Shandong VECM results

Province Name:	Henan
Province ID:	116
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1600	23207	7794
	ELC	28	227.8	2748	997.5
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.28	(0.446)	-2.31	(0.016)**
	ELC	-2.31	(0.428)	-2.03	(0.028)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.2293	-0.1312		
	1	-8.145	-7.850		
	2	-8.398	-7.907		
	3	-8.644	-7.957		
	4	-8.820	-7.937		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	111.0	9.05	13.33	15.41
	1	114.7	1.67	2.69	3.76
	2	115.5			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.047	0.094		
		(0.009)***	(0.088)*		
	ECT_{t-1}	-0.101	0.050		
		(0.050)**	(0.753)		
	ΔRGRP				
	L1	0.551	0.279		
		(0.004)***	(0.633)		
	L2	-0.157	-0.264		
		(0.343)	(0.604)		
	ΔELC				
	L1	-0.012	0.179		
		(0.894)	(0.527)		
	L2	-0.080	-0.113		
		(0.368)	(0.680)		
Joint F-test (p-values)					
		Dependent variable			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.826)		
	ΔELC	(0.666)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.018)**			
	2	(0.530)			
	3	(0.694)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 28: Henan VECM results

Province Name:	Hubei
Province ID:	117
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1170	15145	5002
	ELC	28	193.0	1508	610.2
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.81	(0.192)	-2.05	(0.027)**
	ELC	-1.37	(0.869)	-1.91	(0.035)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.4484	-0.3502		
	1	-8.911	-8.616		
	2	-9.133	-8.642		
	3	-8.988	-8.301		
	4	-8.880	-7.996		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	126.7	6.95	13.33	15.41
	1	129.7	0.786	2.69	3.76
	2	130.1			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.037	0.018		
		(0.014)**	(0.529)		
	ECT_{t-1}	-0.055	0.110		
		(0.199)	(0.176)		
	ΔRGRP				
	L1	0.604	0.271		
		(0.000)***	(0.357)		
	ΔELC				
	L1	-0.009	0.503		
		(0.939)	(0.022)**		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.648)			
	2	(0.993)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 29: Hubei VECM results

Province Name:	Hunan
Province ID:	118
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1249	15160	5057
	ELC	28	156.3	1347	530.6
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.60	(0.792)	-2.09	(0.025)**
	ELC	-2.46	(0.351)	-2.49	(0.011)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.4374	0.5355		
	1	-8.089	-7.795		
	2	-8.322	-7.831		
	3	-8.956	-8.269		
	4	-9.245	-8.361		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	110.6	32.2	13.33	15.41
	1	123.7	5.78	2.69	3.76
	2	126.6			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	-0.019	0.073		
		(0.113)	(0.341)		
	ECT_{t-1}	-0.052	-0.014		
		(0.000)***	(0.822)		
	ΔRGRP				
	L1	0.690	0.289		
		(0.000)***	(0.781)		
	L2	-0.684	-0.787		
		(0.000)***	(0.421)		
	ΔELC				
	L1	-0.079	0.334		
		(0.045)**	(0.179)		
	L2	-0.059	-0.103		
		(0.130)	(0.679)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.716)		
	ΔELC	(0.012)**	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.656)			
	2	(0.615)			
	3	(0.406)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 30: Hunan VECM results

Province Name:	Guangdong
Province ID:	119
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1837	46897	15531
	ELC	28	183.7	4619	1666
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.92	(0.643)	-2.52	(0.011)**
	ELC	-1.72	(0.743)	-1.52	(0.073)*
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.2184	-0.1202		
	1	-8.245	-7.950		
	2	-8.575	-8.084		
	3	-9.187	-8.500		
	4	-9.213	-8.329		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	117.4	18.4	13.33	15.41
	1	124.0	5.09	2.69	3.76
	2	126.6			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.009	0.114		
		(0.753)	(0.134)		
	ECT_{t-1}	-0.251	0.020		
		(0.008)***	(0.935)		
	ΔRGRP				
	L1	1.00	0.939		
		(0.000)***	(0.079)*		
	L2	-0.715	-1.34		
		(0.001)***	(0.014)**		
	ΔELC				
	L1	-0.283	0.111		
		(0.010)**	(0.698)		
	L2	0.116	0.388		
		(0.381)	(0.258)		
Joint F-test (p-values)					
		Dependent variable			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.046)**		
	ΔELC	(0.032)**	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.123)			
	2	(0.061)*			
	3	(0.541)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 31: Guangdong VECM results

Province Name:	Guangxi
Province ID:	120
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	651.6	9169	3008
	ELC	28	81.8	1154	396.7
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.17	(0.917)	-3.57	(0.001)***
	ELC	-3.05	(0.118)	-1.99	(0.031)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-1.332	-1.234		
	1	-8.571	-8.277		
	2	-9.104	-8.613		
	3	-9.394	-8.707		
	4	-9.433	-8.549		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	116.9	10.9	13.33	15.41
	1	122.1	0.473	2.69	3.76
	2	122.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.006	0.070		
		(0.744)	(0.068)*		
	ECT_{t-1}	-0.254	0.020		
		(0.018)**	(0.932)		
	ΔRGRP				
	L1	0.781	0.501		
		(0.000)***	(0.297)		
	L2	-0.429	-0.150		
		(0.018)**	(0.711)		
	ΔELC				
	L1	-0.042	0.191		
		(0.776)	(0.559)		
	L2	0.039	-0.225		
		(0.774)	(0.458)		
Joint F-test (p-values)					
		Dependent variable			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.548)		
	ΔELC	(0.906)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.082)*			
	2	(0.525)			
	3	(0.743)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 32: Guangxi VECM results

Province Name: Guizhou
Province ID: 124
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	423.7	4470	1531
	ELC	28	73.0	1047	370.8
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	1.12	(1.000)	-0.287	(0.389)
	ELC	-3.11	(0.105)	-3.32	(0.002)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.7556	0.8538		
	1	-7.745	-7.450		
	2	-7.445	-6.954		
	3	-7.482	-6.794		
	4	-7.588	-6.704		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	96.3	24.8	13.33	15.41
	1	108.2	0.956	2.69	3.76
	2	108.7			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	-0.069	0.131		
		(0.000)***	(0.444)		
	ECT_{t-1}	0.016	0.009		
		(0.000)***	(0.749)		
	ΔRGRP				
	L1	0.056	-0.857		
		(0.734)	(0.563)		
	L2	-0.356	0.019		
		(0.033)**	(0.990)		
	ΔELC				
	L1	-0.008	-0.133		
		(0.735)	(0.527)		
	L2	-0.037	-0.423		
		(0.104)	(0.039)**		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.846)		
	ΔELC	(0.263)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.435)			
	2	(0.432)			
	3	(0.774)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 33: Guizhou VECM results

Province Name: Yunnan
Province ID: 125
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	652.5	7523	2640
	ELC	28	75.7	1316	415.2
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	0.077	(0.995)	-1.26	(0.111)
	ELC	-1.69	(0.755)	-1.80	(0.043)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.1578	-0.0596		
	1	-9.039	-8.744		
	2	-8.986	-8.495		
	3	-8.780	-8.093		
	4	-8.934	-8.051		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	105.5	11.1	13.33	15.41
	1	110.4	1.09	2.69	3.76
	2	111.0			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.080	0.078		
		(0.000)***	(0.174)		
	ECT_{t-1}	-0.128	0.129		
		(0.010)***	(0.485)		
	ΔRGRP				
	L1	-0.071	0.471		
		(0.703)	(0.499)		
	ΔELC				
	L1	0.030	0.019		
		(0.647)	(0.939)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.426)			
	2	(0.791)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 34: Yunnan VECM results

Province Name:	Gansu
Province ID:	128
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	312.5	4020	1402
	ELC	28	125.8	994.6	380.1
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.56	(0.807)	-1.31	(0.104)
	ELC	-1.54	(0.814)	-1.51	(0.075)*
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.3458	0.4439		
	1	-9.190	-8.896		
	2	-9.083	-8.592		
	3	-9.616	-8.928		
	4	-9.777	-8.893		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	117.6	35.4	13.33	15.41
	1	133.2	4.20	2.69	3.76
	2	135.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.032	-0.043		
		(0.039)**	(0.635)		
	ECT_{t-1}	0.025	0.018		
		(0.000)***	(0.446)		
	ΔRGRP				
	L1	0.239	0.528		
		(0.069)*	(0.496)		
	L2	-0.389	-1.92		
		(0.003)***	(0.014)**		
	L3	-0.354	1.50		
		(0.010)***	(0.063)*		
	ΔELC				
	L1	-0.049	0.443		
		(0.191)	(0.044)**		
	L2	0.027	-0.186		
		(0.452)	(0.385)		
	L3	0.002	0.147		
		(0.951)	(0.478)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.051)*		
	ΔELC	(0.586)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.939)			
	2	(0.321)			
	3	(0.604)			
	4	(0.879)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 35: Gansu VECM results

Province Name:	Qinghai
Province ID:	129
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	118.8	1205	406.8
	ELC	28	17.2	602.2	162.4
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.53	(0.313)	-1.00	(0.164)
	ELC	-2.13	(0.527)	-3.20	(0.002)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.3865	-0.2883		
	1	-7.826	-7.531		
	2	-8.235	-7.744		
	3	-8.368	-7.681		
	4	-8.195	-7.311		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	99.9	22.0	13.33	15.41
	1	108.2	5.50	2.69	3.76
	2	110.9			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.036	0.007		
		(0.000)***	(0.915)		
	ECT_{t-1}	-0.029	0.156		
		(0.002)***	(0.010)**		
	ΔRGRP				
	L1	0.592	1.92		
		(0.000)***	(0.019)**		
	ΔELC				
	L1	-0.080	0.135		
		(0.005)***	(0.468)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.197)			
	2	(0.609)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 36: Qinghai VECM results

Province Name:	Ningxia
Province ID:	130
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	27	128.9	1305	468.3
	ELC	28	24.6	741.8	215.9
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-0.958	(0.949)	-1.80	(0.043)**
	ELC	-1.79	(0.711)	-3.61	(0.001)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.1503	0.2491		
	1	-7.781	-7.485		
	2	-7.576	-7.082		
	3	-7.904	-7.213		
	4	-7.995	-7.107		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	91.8	31.6	13.33	15.41
	1	103.4	8.36	2.69	3.76
	2	107.5			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	-0.027	0.035		
		(0.185)	(0.790)		
	ECT_{t-1}	0.061	0.046		
		(0.000)***	(0.494)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.517)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 37: Ningxia VECM results

Province Name:	Xinjiang
Province ID:	131
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	454.3	5206	1920
	ELC	28	37.7	1152	259.6
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.14	(0.523)	-1.95	(0.034)**
	ELC	1.25	(1.000)	1.21	(0.879)
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.2261	0.3243		
	1	-8.870	-8.575		
	2	-9.673	-9.182		
	3	-9.551	-8.864		
	4	-9.328	-8.445		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	125.5	8.92	13.33	15.41
	1	129.9	0.015	2.69	3.76
	2	129.9			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.057	0.003		
		(0.035)**	(0.944)		
	ECT_{t-1}	0.020	-0.349		
		(0.790)	(0.007)***		
	ΔRGRP				
	L1	0.584	0.667		
		(0.020)**	(0.125)		
	L2	-0.282	0.148		
		(0.330)	(0.768)		
	L3	-0.182	0.549		
		(0.499)	(0.240)		
	ΔELC				
	L1	0.233	0.802		
		(0.191)	(0.009)***		
	L2	-0.076	-0.347		
		(0.727)	(0.355)		
	L3	0.010	-0.126		
		(0.954)	(0.675)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.168)		
	ΔELC	(0.609)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.190)			
	2	(0.193)			
	3	(0.904)			
	4	(0.515)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 38: Xinjiang VECM results

Province Name:	China
Province ID:	132
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	33317	359669	137217
	ELC	28	4118	49763	17907
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-2.55	(0.304)	-3.93	(0.001)***
	ELC	-1.47	(0.841)	-2.70	(0.008)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.6631	-0.5649		
	1	-9.016	-8.721		
	2	-9.599	-9.109		
	3	-9.990	-9.303		
	4	-10.31	-9.430		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	136.3	10.9	13.33	15.41
	1	141.4	0.743	2.69	3.76
	2	141.8			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.044	-0.006		
		(0.209)	(0.894)		
	ECT_{t-1}	0.033	0.228		
		(0.597)	(0.008)***		
	ΔRGRP				
	L1	0.895	-0.516		
		(0.001)***	(0.181)		
	L2	-0.891	0.007		
		(0.006)***	(0.987)		
	L3	0.034	-0.812		
		(0.910)	(0.048)**		
	ΔELC				
	L1	-0.076	1.03		
		(0.652)	(0.000)***		
	L2	0.162	-0.682		
		(0.478)	(0.030)**		
	L3	0.214	0.973		
		(0.288)	(0.000)***		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.021)**		
	ΔELC	(0.238)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.189)			
	2	(0.436)			
	3	(0.379)			
	4	(0.760)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 39: China VECM results

Province Name:	SichChong
Province ID:	134
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1860	26397	8289
	ELC	28	244.2	2554	954.5
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-0.994	(0.945)	-1.64	(0.058)*
	ELC	-2.61	(0.273)	-4.54	(0.000)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-1.529	-1.431		
	1	-8.756	-8.462		
	2	-8.726	-8.235		
	3	-8.485	-7.798		
	4	-8.324	-7.440		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	109.7	28.6	13.33	15.41
	1	122.0	3.94	2.69	3.76
	2	124.0			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	-0.014	0.060		
		(0.465)	(0.220)		
	ECT_{t-1}	-0.053	-0.013		
		(0.000)***	(0.579)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.543)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 40: Sichuan VECM results

Province Name:	Southern China Power Grid
Province ID:	135
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	3565	68060	22710
	ELC	28	414.2	8136	2849
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.95	(0.010)**	-2.71	(0.008)***
	ELC	-3.61	(0.029)**	-3.27	(0.002)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-1.005	-0.9067		
	1	-9.133	-8.838		
	2	-9.234	-8.744		
	3	-9.536	-8.849		
	4	-10.30	-9.419		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	130.7	21.8	13.33	15.41
	1	141.6	0.002	2.69	3.76
	2	141.6			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.085	0.013		
		(0.011)**	(0.816)		
	ECT_{t-1}	-0.122	0.802		
		(0.451)	(0.003)***		
	ΔRGRP				
	L1	0.810	0.435		
		(0.001)***	(0.267)		
	L2	-0.656	-1.08		
		(0.021)**	(0.021)**		
	L3	-0.119	-0.553		
		(0.595)	(0.133)		
	ΔELC				
	L1	-0.038	0.895		
		(0.787)	(0.000)***		
	L2	0.003	0.068		
		(0.984)	(0.777)		
	L3	0.222	1.14		
		(0.084)*	(0.000)***		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.000)***		
	ΔELC	(0.218)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.009)***			
	2	(0.268)			
	3	(0.343)			
	4	(0.153)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 41: Southern Power Grid VECM results

Province Name:	East China Power Grid
Province ID:	136
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	6435	113788	37801
	ELC	28	833.1	12086	4175
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-3.67	(0.024)**	-2.65	(0.008)***
	ELC	-2.15	(0.520)	-1.75	(0.047)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	0.3396	0.4377		
	1	-7.738	-7.444		
	2	-8.204	-7.714		
	3	-8.001	-7.314		
	4	-7.961	-7.077		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	116.9	4.84	13.33	15.41
	1	119.3	0.053	2.69	3.76
	2	119.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.053	0.012		
		(0.070)*	(0.747)		
	ECT_{t-1}	-0.026	0.116		
		(0.665)	(0.116)		
	ΔRGRP				
	L1	0.471	-0.212		
		(0.017)**	(0.389)		
	ΔELC				
	L1	0.130	0.682		
		(0.419)	(0.001)***		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.678)			
	2	(0.360)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 42: East China Power Grid VECM results

Province Name: Northeast China Power Grid
Province ID: 137
Sample Period: 1985-2012
RGRP: Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC: Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	3808	49463	16047
	ELC	28	756.7	5382	2184
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.79	(0.711)	-1.17	(0.127)
	ELC	-1.05	(0.936)	-1.79	(0.044)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.2372	-0.1390		
	1	-8.231	-7.937		
	2	-8.086	-7.596		
	3	-8.240	-7.552		
	4	-8.192	-7.308		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	111.3	6.00	13.33	15.41
	1	113.4	1.73	2.69	3.76
	2	114.3			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.021	-0.007		
		(0.163)	(0.851)		
	ECT_{t-1}	0.056	0.174		
		(0.177)	(0.078)*		
	ΔRGRP				
	L1	0.511	0.105		
		(0.004)***	(0.805)		
	ΔELC				
	L1	0.098	0.118		
		(0.285)	(0.591)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.161)			
	2	(0.199)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 43: North-east China Power Grid VECM results

Province Name:	North China Power Grid
Province ID:	138
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	5840	93625	31029
	ELC	28	892.6	10235	3814
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-4.37	(0.002)***	-2.07	(0.026)**
	ELC	-1.69	(0.754)	-1.96	(0.032)**
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.0765	0.0217		
	1	-8.217	-7.922		
	2	-8.455	-7.964		
	3	-8.461	-7.774		
	4	-8.553	-7.670		
Johansen test for co-integration	**No. co-integrating equations**			**Critical values**	
		LL	**Trace**	**10%**	**5%**
	0	120.1	4.05	13.33	15.41
	1	122.1	0.046	2.69	3.76
	2	122.1			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.046	-0.001		
		(0.027)**	(0.990)		
	ECT_{t-1}	0.002	0.173		
		(0.966)	(0.089)*		
	ΔRGRP				
	L1	0.553	0.175		
		(0.001)***	(0.622)		
	ΔELC				
	L1	0.012	0.402		
		(0.912)	(0.066)*		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.313)			
	2	(0.176)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 44: North China Power Grid VECM results

Province Name:	Northwest China Power Grid
Province ID:	139
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	1557	21786	7347
	ELC	28	317.5	4585	1412
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	0.481	(0.997)	-0.574	(0.287)
	ELC	-1.36	(0.874)	-1.33	(0.101)
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.1239	-0.0257		
	1	-9.851	-9.557		
	2	-9.755	-9.264		
	3	-9.937	-9.249		
	4	-10.82	-9.937		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	120.5	54.7	13.33	15.41
	1	146.3	3.00	2.69	3.76
	2	147.8			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	0.036	-0.035		
		(0.000)***	(0.499)		
	ECT_{t-1}	0.031	0.032		
		(0.000)***	(0.107)		
	ΔRGRP				
	L1	0.065	0.222		
		(0.467)	(0.721)		
	L2	-0.328	-0.962		
		(0.000)***	(0.103)		
	L3	-0.306	0.551		
		(0.000)***	(0.179)		
	ΔELC				
	L1	0.002	0.487		
		(0.955)	(0.023)**		
	L2	0.020	-0.385		
		(0.545)	(0.093)*		
	L3	0.047	0.322		
		(0.148)	(0.151)		
Joint F-test (p-values)		**Dependent variable**			
		ΔRGRP	ΔELC		
	ΔRGRP	-	(0.153)		
	ΔELC	(0.366)	-		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.250)			
	2	(0.910)			
	3	(0.774)			
	4	(0.353)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 45: Northwest China Power Grid VECM results

Province Name:	Central China Power Grid
Province ID:	140
Sample Period:	1985-2012
RGRP:	Real Gross Regional Product at 2005 prices (100 million Yuan)
ELC:	Electricity consumption (100 million kWh)

Summary statistics					
		Sample Size	**Minimum**	**Maximum**	**Mean**
	RGRP	28	6586	88940	29163
	ELC	28	906.0	9024	3396
ADF test					
		Levels		**First Difference**	
		Z	**p-value**	**Z**	**p-value**
	RGRP	-1.47	(0.839)	-2.12	(0.023)**
	ELC	-1.73	(0.738)	-3.28	(0.002)***
Lag selection					
	Lag	**AIC**	**SBIC**		
	0	-0.7326	-0.6344		
	1	-9.212	-8.918		
	2	-9.346	-8.855		
	3	-9.597	-8.910		
	4	-9.679	-8.795		
Johansen test for co-integration	**No. co-integrating equations**	**LL**	**Trace**	**Critical values 10%**	**5%**
	0	118.3	28.3	13.33	15.41
	1	131.7	1.42	2.69	3.76
	2	132.4			
VEC Results					
		Dependent variable			
		ΔRGRP	ΔELC		
	Constant	-0.014	0.058		
		(0.453)	(0.201)		
	ECT_{t-1}	-0.121	-0.029		
		(0.000)***	(0.553)		
LM test for serial correlation	**Lag**	**p-value**			
	1	(0.693)			

Note: P-values are in parentheses
***,**,* represent significance at the 1%, 5%, and 10% levels respectively

Table 46: Central China Power Grid VECM results

D Granger causality maps

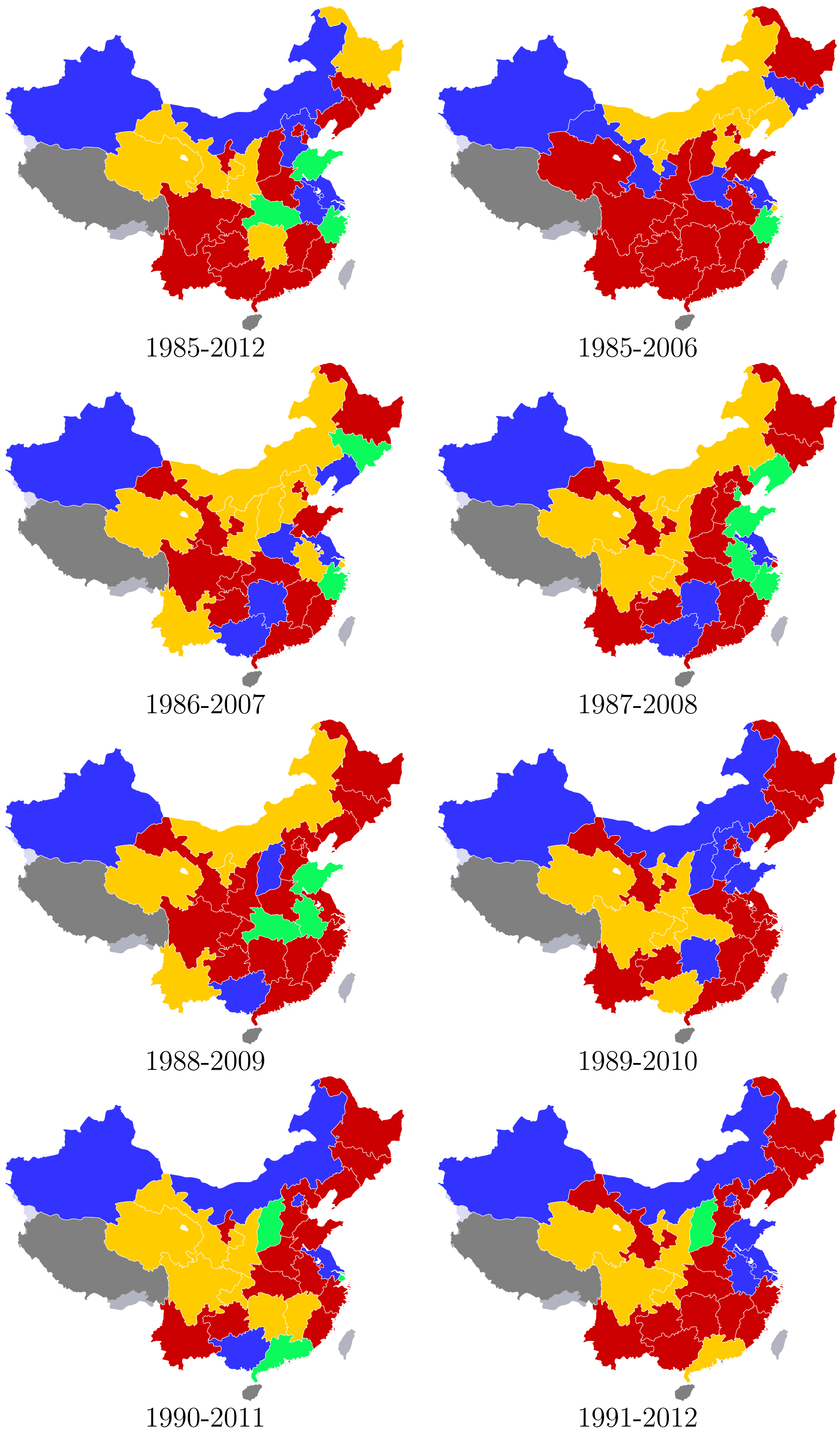

Figure 47: Long run Granger causality maps for different sample periods

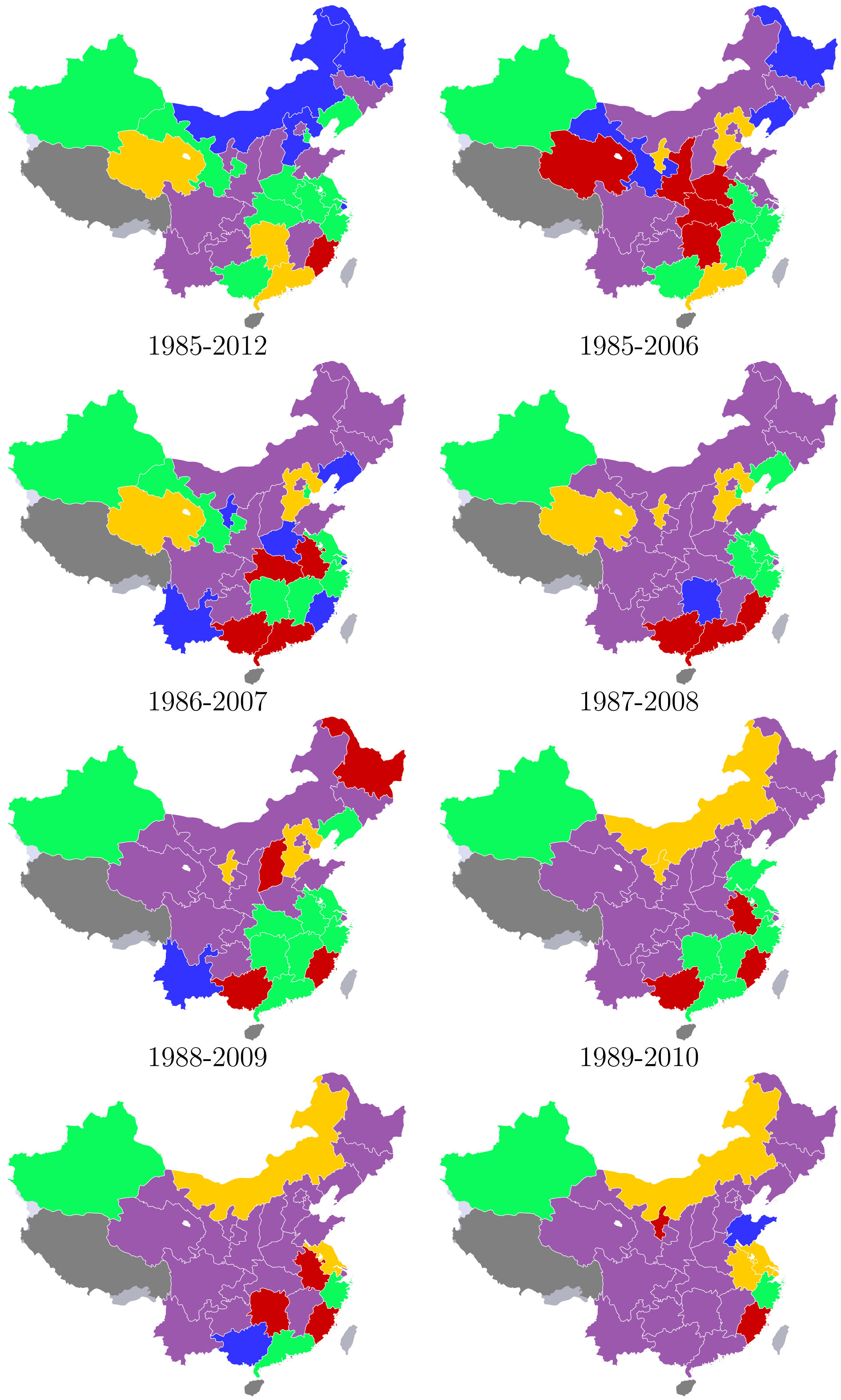

Figure 48: Short run Granger causality maps for different sample periods