Nightlights as a Development Indicator: The Estimation of Gross Provincial Product (GPP) in Turkey

Basihos, Seda

The Economic Policy Research Foundation of Turkey

5 May 2016

Nightlights as a Development Indicator:
The Estimation of Gross Provincial Product (GPP) in Turkey

*[1]

Abstract

For a while in Turkey, researchers dealing with spatial economics are unable to make detailed comparative and descriptive analysis on sub-national base due to lack of data. In particular, GDP, which is a basic indicator of economic activities, has not been published in Turkey at sub-national level since 2001. In this study, we use a different data source, night-time satellite imagery, to obtain sub-national GDP and GDP per capita series for the period between 2001 and 2013 at the level of provinces which is the basic administrative division of the Country. We also re-construct the series for the period between 1992 and 2001. For the estimation of sub-national GDP, we use Neural Network Algorithm.

Estimating national-level economic activities, such as GDP, economic growth etc., is full of challenges. Doing so at sub-national level is even more compelling due to data challenges, and difficulties in recording economic activity at sub-national level. Turkey is not an exception. Since 2001 TurkStat has not calculated GDP at provincial level, hereinafter referred to as the Gross Provincial Product (GPP), due to statistical and logistic difficulties. However, estimating GPP is becoming increasingly policy relevant in Turkey. First, there is a policy interest to see how domestic product is allocated into different parts of the country. From the central government perspective it is needed to design location based policy priorities. Second, provinces themselves may want to know how much they contribute to GDP, and how they stack-up against their counter peers. Last, such information could help to clear uncertainty before investors who plan to undertake investments.

This study aims to estimate GPP and GPP per capita which have not been calculated since 2001 by TurkStat. In the literature, there is much well-established research demonstrating that nightlight is a good proxy measure of the economic activities. Note that the most compelling task of this study is to derive a series which is not available at all. Therefore, it is almost impossible to estimate GPP of Turkey with nightlights using classical econometric models due to

- Lack of information on provincial basis or lack of provincial data of other economic variables which could be put into regression
- GPP only available in limited time interval, 1992-2001, or small sample size
- Noisy nature of nightlights series and nonlinear relationship of nightlights with economic variables[2]

*[1] I would like to thank Prof. Dr. Güven Sak, Prof. Dr. Erol Taymaz, Geomorphologist İlker Alan (Turkish State Meteorological Service), Program Coordinator of City Studies in Economic Policy Research Foundation of Turkey (TEPAV), Emre Koyuncu, for their invaluable comments. Also, I would like to thank Policy Analysts of TEPAV, Can İtez, Ayşegül Taşöz Düşündere and Yasemin Satır Çilingir, for their great supports.

Basically, our study has a specific feature since we use statistical instruments without searching for economic conclusion. In accordance with the aim of the study and data related bottlenecks given above, we use Neural Network method to *estimate* GPP series between 1992 and 2013. Neural Network that we develop allows us to use other variables in the model without specifying them. These are the variables along with nightlights which explain GDP in the model. Simply, we find six other variables explaining GDP, which are later denoted as hidden neurons. Also, we have to create a system in which these six variables and nightlights explain GDP in a-good fit. This system is such that all variables are governed by specific parameters in, which is later denoted as hidden layer. To repeat, the main aim of the study is to estimate GPP as much as close to exact values. Therefore, we go beyond underlying economic relationships, and apply deep statistical manipulation. It means that we use nightlights data as a tool or *referee variable* for our estimation.

In summary, first we mention the related literature about the estimation of magnitude of economic activities with nightlights. In this section, we also briefly mention how Neural Network algorithm is used to predict economic growth when various unknown parameters exist. Second, we explain how we extract the corresponding data from satellite imagery. Third, we estimate national GDP with nightlights in order to check the structural validation for further calculations. Lastly, we estimate GPP of Turkey for the period between 2001 and 2013, and reconstruct the series between 1992 and 2001. We also provide GGP per capita series between 1992 and 2013 in this section.[3]

Related Literature on Usage of Nightlights as a Proxy and Neural Network Analysis

The luminosity studies so far aim to examine the underlying relationship between nightlights and economic variables such as GDP growth, development and population. Sometimes, nightlights are used to create an index of development, a density ratio of human settlements, etc. Neural Networks, on the other hand, is an alternative estimation method in the econometrics used for complex systems. These are the black box models which do not need giving an economic meaning to the estimated relationship.

Here we first review the literature of nightlights as a proxy measure in an economy, and we second briefly mention concerning areas of Neural Networks in econometrics.

William Nordhaus of Yale University states that about 3,000 studies have used nightlights as a proxy of economic activities since 2000. Nordhaus and Chen (2010) statistically examine how well nightlights can help researchers to measure economic activities of the countries. They find that satellite

[2] Wu et al. (2013) find that light consumption per capita has inverted U-shaped relationship with GDP per capita.
[3] In the last section, we also clear the statistical discrepancy between sum of GPP and GDP of Turkey which TurkStat published for period between 1992 and 2001. For instance, there is 34.64-percent gap between Turkey's real GDP and summation of GPP for the year 2001

images are very useful in assessing economic activities of cities and regions. They also note that traditional data sources are often far less reliable. The studies show that nightlights can be used as a proxy for many variables such as urbanization, city dynamics, population movements, economic growth, development indicator and so on. Mellander et al. (2015) examine the correlation between population density and nightlights by using geo-coded residential and industrial micro data of Sweden and both radiance and saturated lights emissions. They find a strong correlation to make nightlights a relatively good proxy for economics activities.[4]

Doll et. al (2006), based on the data of 11 European Union Countries and the United States, maps regional economic activity from nightlights satellite images. They find that there is a strong positive relationship between the nightlight series and GDP across a range of spatial scale. Also, Authors of World Bank, Bundervoet et al. (2015), estimate GDP growth rates and levels for 47 counties in Kenya and 30 districts in Rwanda by using satellite imagery. Forbes (2015) examines whether there is a statistical correlation between GDP and nightlights data at Metropolitan Statistical Era (MSA) of Florida. Forbes (2015) not only finds strong correlation but he also detects specific industries within each MSA contributing to the variance of nightlights at the greatest amount.

Gosh et al. (2013) use the radiance-calibrated nightlights as a proxy measure of human well-being at both national and sub-national level. One way that they review is regressing sum of lights intensity values for countries against their official GDP plus informal economy. They create 36 overlapping groups of administrative units at different levels of economic development with ratios of sum of light intensity to official GDP and GSP (Gross Sub-National Product) plus informal economy.[5] The regression model calibrates the sum of lights intensity to the official GDP values or GSP plus informal economy for all 36 groups. They obtained R^2 greater than 0.9 for all groups.

Sutton et al. (2007) estimate GDP at sub-national level for the countries, China, India, Turkey, and the United States. The study stays limited to estimate sub-national GDP as a time series although it provides beneficial instruments in the starting point. Briefly, they use two different methods; first one is aka summation of light intensity values (Ebener et al., 2005); and second one is spatial analytic approach using areal extent of lit area and non-linear relationship between nightlights and population. After disaggregating the DMSP OLS according to sub-national administrative units, sub-national level lights integrations (first and second) are regressed against to sub-national level GDP values of corresponding countries including Turkey. The residuals from the regression models, which are divided into 5 quintiles, are used to create regional parameters. In order to predict sub-national GDP in 2000, they apply regional parameters derived from errors in 1992-1993 data to the 2000 data. However, Sutton et al. (2007) argue that aka summation of light intensity suffers from saturation of

[4] They also find stronger correlation between economic activities and radiance lights compared to saturated lights.
[5] Gosh et al. (2013) take the estimates of informal economy as a percentage from Schneider's computation.

nightlights in urban core centers. For example, R^2 of first simple model is 0.58 for Turkey. However, R^2 increases dramatically to 0.95 in second approach. They suppose that the reason of improvement is due to the fact that İstanbul is a single giant city composing large fraction of GDP of its nation. Therefore, this simple model relatively fails to estimate without correcting DMSP OLS regarding areal lit.

One of the most pronounced studies is conducted by Vernon Henderson, Adam Storeygard and David Weil from Brown University in 2009.[6] In their study, the intensity of outer space lights, i.e. nightlights, emitted from the countries as an outcome of electricity consumption is used for the measurement of true GDP of 188 countries over 17 years. In addition, they provide long-term picture of differences in income of South and North Korea. For the first time, Henderson et al. (2009) use nightlights as a tool, more than a proxy, to correct GDP series of 188 countries. Moreover, Pinkovskiy and Sala-i Martin (2016) use nightlights as a *referee variable* to compare national accounts GDP per capita to survey means in measuring true GDP of India and Angola. The spirit of their study is very close to Henderson et al. (2008). In both study, the measurement errors of official GDP are assumed to be uncorrelated with the errors resulting from physical conditions affecting luminosity record quality. This is the necessary assumption for our study, as well.

Both Henderson (et al., 2008) and Pinkovskiy and Sala-i Martin (2016) benefit nightlights to correct miscalculated official GDP of some countries. However, we use a different method to benefit nightlights as a tool to estimate national and sub-national level GDP due to the reasons mentioned earlier. The method we exploit is the Neural Networks analysis. Kuan and White (1994) are the first ones giving the definitive introduction of Neural Network to the econometric literature. Their theoretical approaches are applied by Maasoumi et al. (1994) who show that fourteen macroeconomic series would be well-modeled with Neural Networks. Tkacz and Hu (1999) examine whether forecasting performance of financial and monetary variables for output growth can be improved using Neural Networks. They find that neural network predict GDP growth with less errors compared to its linear counterparts such as ARIMA.

Feng and Zhang (2014) show the application of artificial neural network in forecasting economic growth. They obtain a map of stimuli effect of various known and unknown variables over GDP growth via combination of nonlinear functions. In addition, Sokolov-Mladenovic et al. (2016) predict the economic growth based on trade indicators with two different neural network algorithms.
Considering both the implementation of neural network in macroeconomic analysis and using nightlights as an indicator for economic activities, there are novel literatures. Among many approaches

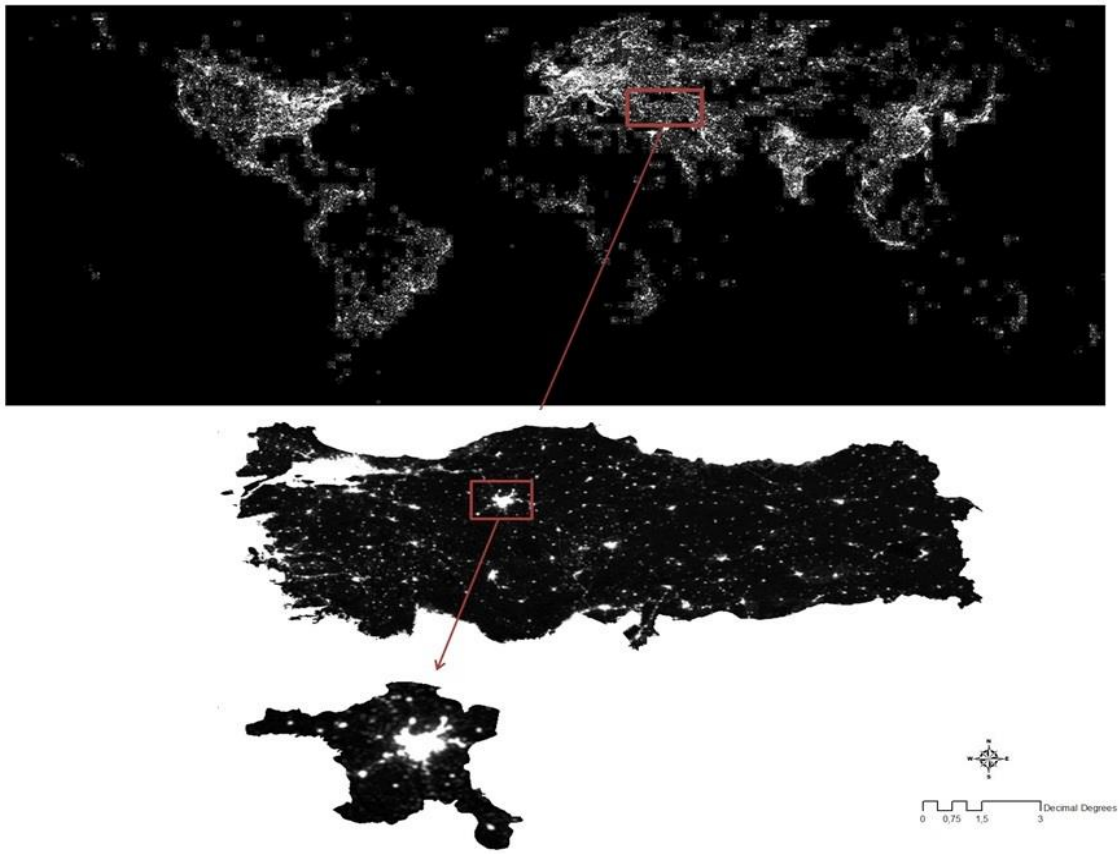
[6] See also Narayan, P. K., & Prasad, A. (2008). Electricity consumption–real GDP causality nexus: Evidence from a bootstrapped causality test for 30 OECD countries. *Energy Policy*, *36*(2), 910-918.

the combination of these two seems to create an accurate solution for the question and conditions specific to Turkey's data in hand.

Nightlights Data

We use Optical Linescan System (DMSP-OLS) Nighttime Lights Time Series from Defense Meteorological Satellite Program Optical Linescan System (DMSP-OLS) which is available on the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center (NGDC).[7] NOAA has been keeping a digital archive for DMSP data since 1992. The latest version of the satellite image is for the year 2013. The nightlight series is published with 2 or 3-year gap due to demanding recording and computing process.

Figure 1 Global Night Lights, 2013



Source: The Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)

[7] Polar weather satellites circle the earth 14 times per day, recording the intensity of Earth-based lights. Each satellite observes every location on Earth every night at an instant between 8:30 and 22:00 local time. The National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center (NGDC) process the raw data, and remove intense sources of natural light, which leaves mostly man-made light.[7] Each satellite-year dataset is a grid reporting the intensity of lights as a six-bit digital number, for every 30 arc-second output pixel (approximately 0.86 square kilometers at the equator) between 65 degrees south and 75 degrees north latitude. Pixel values of infrared images between 190 and 130 Kelvin temperature are stored under 256-scale.

Figure 1 shows the global nightlight map recorded by DMSP. This map is indeed a high dimensional image. It is possible to obtain nightlight data of regions and sub-regions by masking out administrative boundaries using the same coordinate system.

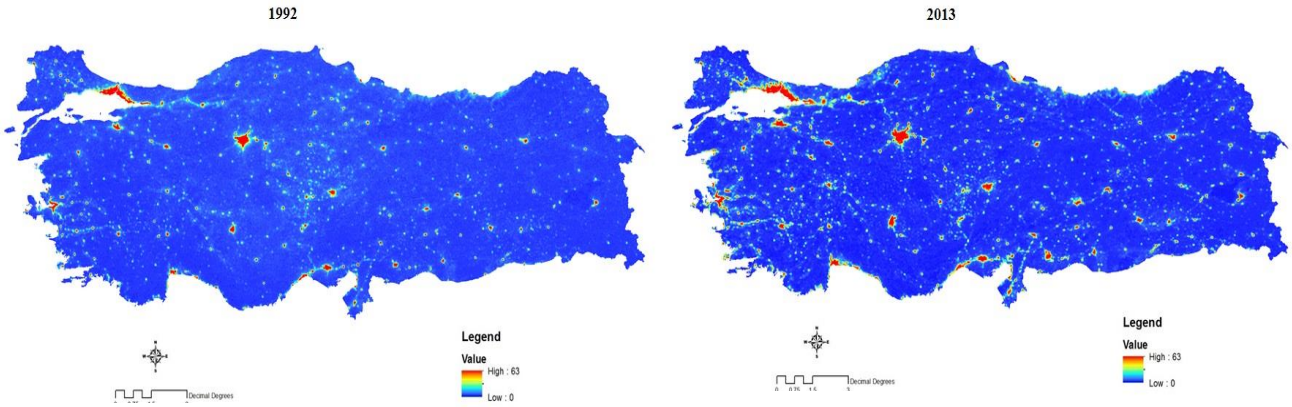
How to obtain raw data from night lights images?

First, we extract (by-mask) the raster of the nightlights of each year between 1992 and 2013 by a polygon feature. Sonar scale of the nightlights image is actually between 0 and 255. By extracting, we obtain a multiband raster which is re-scaled between 0-63 in RGB (red-green-blue) form.[8] This process also allows us to clear the effect of natural lights, such as the bright half of the lunar cycle, auroral activity (the northern and southern lights) and moon light, etc.. Then we extract Turkey from the global map which is already re-scaled between 0-63 in RGB. Lastly, we weigh the number of pixels obtained from this process by corresponding digital number, i.e, DN, (0-63). The sum of weighted number of pixel gives the numerical nightlight intensity of Turkey.

$$X_t = \sum_{i=0}^{63} i * (the\ number\ of\ pixels); \quad (1)$$

$$DN{=}i\ and\ X_t\ is\ nightlight\ of\ Turkey\ in\ time\ t$$

Figure 3 Nightlights of Turkey, 1992 and 2013



Source: The Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)

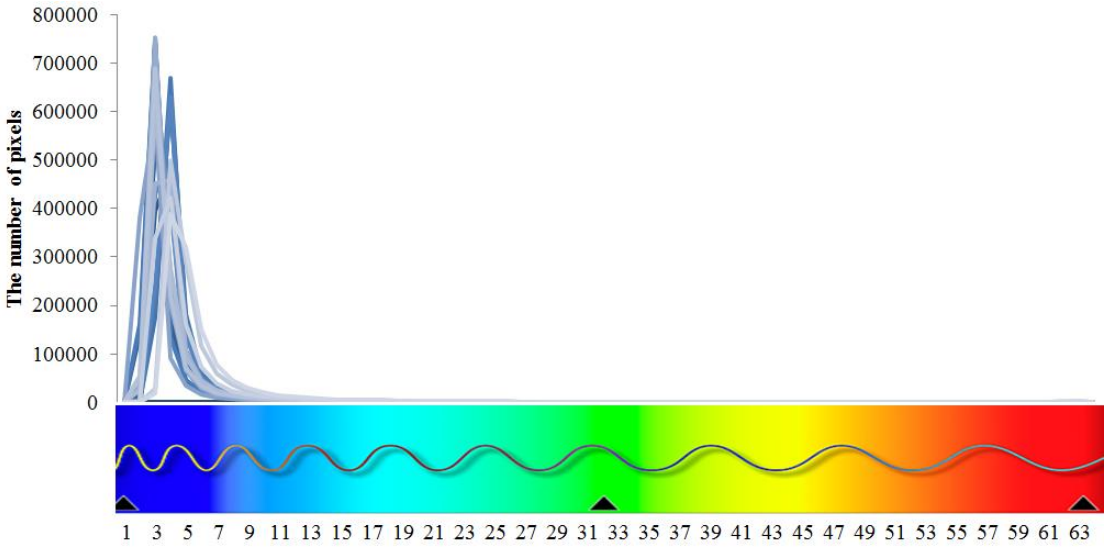
Note: RGB form of night light image of Turkey.

The quality of nightlights data of Turkey is more reliable than Northern countries since it is at latitudes relatively close to the equator. However, Turkey still is geographically located in the North-East. This

[8] The digital number is an integer between 0 (no light) and 63.

situation may have negligible effect over the data quality of the Eastern Region, which shall not affect the results of our analysis.[9]

Figure 4 Distribution of nightlights between 0-63: Turkey, 1992-2013



Source: The Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS), and our calculations

0 in the scale refers to no lights and the last nail in the scale, 63, refers to the brightest. Thus, the sensor saturates at a level of light in top-coded values. The distribution of light in the range 0-63 indicates that light intensity of Turkey had value around 4 out of 63 in 2013 (Figure 4).

Estimation of GDP by Nightlights

Nightlights series might be distorted due to non-periodic recording, meteorological conditions and technological variation of satellite in some years (Henderson et al., 2009; Fierz-Schmidhauser et. al, 2010). These situations lower the quality of data and hinder the measurement of economic activities. In addition, our sample size is small, and there is only one independent variable, i.e, nightlights. These would cause a larger error term. However, we use two different methods to eliminate these problems. Firstly, we filter time series of nightlights by signal processing (FIR filter) in order to clear the distortions.[10] In this method, frequency of nightlights is synchronized in [0,1] domain. This technique is widely used to identify trends without distorting signal a lot.

[9] "The exclusion of high latitude zones affects approximately ten thousand people, or 0.0002% of the global total, in four countries or country-equivalents, two of which (Canada and Russia) have GDP data" Henderson et. al, 2009

[10] This is also called Signal Smoothing.

Secondly, we build a nonlinear autoregressive model with exogenous variable in order to estimate GDP.[11] For the calibration, we use Neural Network algorithm which is developed based on the relation between neurons of the human brain.[12] For good sample-in fit, we introduce 6 hidden neurons (latent variables) within single hidden layer with a single independent variable, i.e., nightlights.[13] We determine the number of hidden neurons until we obtain the least sum of mean squared error. In this case, our simulation is created from the minimization of error between the base model, which is developed by randomly selected observations, and the original model. This is indeed a kind of optimization (Herbrich et al., 1999).

The chief advantage of neural network in econometrics is the ability to find a solution for complex systems which are free from the assumption of linearity. The output of this model is the combination of logit functions, which transmitted the "information" from one neuron to another. This eventually allows a binary probit model. The model sees the system in layers. The input layer composed of neural units, i.e., independent variable, $X_0, X_1, X_2 \dots, X_n$.[14] The output layer is also composed of dependent variable, GDP. Moreover, GDP is affected by the past values of itself due to dynamic nature of itself. Hence, autoregressive process is introduced within the input layer.

The information only transmits when value of input neural unit exceeds the threshold, ά. In other words, the neural unit will be 1 if the neuron is activated; otherwise, it will be 0 (Shannon and Weaver, 1993).

For simplicity, we represent the structured form in initial time although the model time is discrete. If $t = 1$, the linear network model is such that

$$\mathrm{GDP} = \sum_{j=1}^{j} \mathrm{X_j}\alpha_j \qquad\qquad \alpha > \acute{\alpha} \tag{2}$$

Where α_j, is the network parameter which determines the activation of neuron in information transmission.[15] On the other hand, extra layer would increase the learning capacity of the model. In that case, the relation between two variables will not be direct as we want.

[11] We estimate both current and real GDP of Turkey.
[12] The algorithm creates a self-learning mechanism. The network chooses random observations from the whole sample to build a base model. Firstly, it trains the base model in order to learn the path. During the iterations, it tries to validate the path with saturated model (whole sample). Thus, the main principle of the network is to find a trajectory within the sample which minimizes the error between base and saturated models.
[13] The number of neurons is determined based on the training performance of the model.
[14] X denotes nightlights.
[15] The model is indeed developed to represent dynamic system since GDP is time depended, that is, output of the current is related to the output in past values. Therefore, Equation (2) should be such that; $\mathrm{GDP_t} = \sum_{j=1}^{j} \mathrm{X_{t,j}}\alpha_{t,j} + GDP_{(t-1)}\eta_t$ where the activation of neurons is also constraint by $\eta > \acute{\eta}$. However, for simplicity we represent the structured form in initial time, $t = 1$.

This could be accomplished by a simple threshold function. This function would be logic (sigmoid) as stated above, and such as

$$f(\mu) = \frac{1}{1 + e^{-\mu}} \tag{3}$$

Hence, we allow linear structure to have a non-linear relationship via hidden layer. Thus, the information received from input neurons is firstly processed in a hidden layer, and then transmitted to an output layer (White, 1992).

Since we use a single hidden layer, H_j in our model, we re-adjust such as:

$$\mathrm{H} = f\left[\sum_{j=0}^{j} \mathrm{X_j}\alpha_j\right] \tag{4}$$

and θ_j is weight linking input neurons to hidden neurons

$$\mathrm{GDP} = \sum_{j=0}^{j} \mathrm{H_j}\theta_j \tag{5}$$

Substituting (4) into (5) we get the function of hidden layer, h, including input layer function, g

$$GDP = h[(\textstyle\sum_{k=1}^{k} \alpha_k)\, f(\sum_{j=0}^{j} \theta_{ik} X_j)]. \tag{6}$$

j=one input neuron with one input layer

k=six hidden neurons with one hidden layer

Generally, hidden variables in the network need not to be identified in order to estimate GDP; it can be simply treated as an unknown. However, approximation is not possible without latent (hidden) variable in the network.

Moreover, this network is very sensitive to noise, which means there is a trade-off between the complexity of model and the noise that the system can tolerate (Tkacz and Hu, 1999). Therefore, before building the network, we should clear the distortions in the nightlights series with noise filter processing.

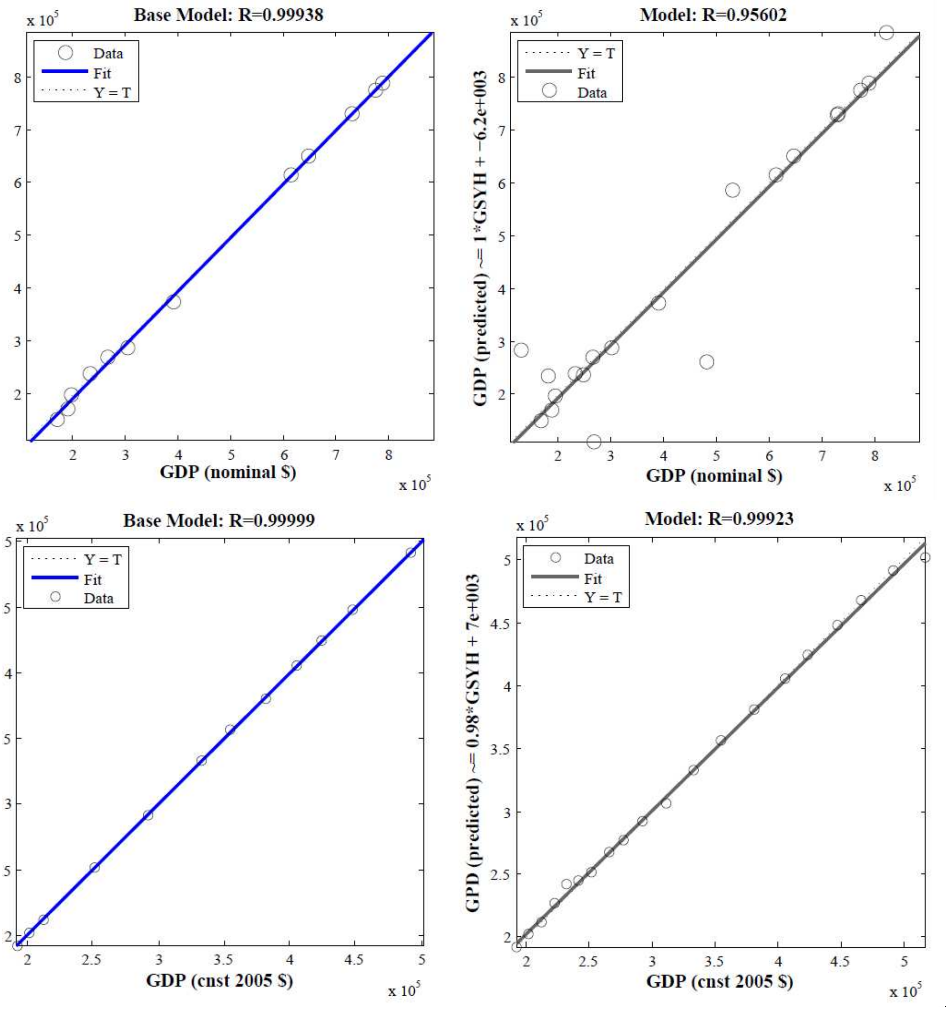
Eventually, we seek to minimize sum of squared deviations between estimation and output layer.

$$\min_{\alpha_k \theta_{jk}} SSD = \sum_{t=1}^{T} \left[GDP_t - h\left(\sum_{k=1}^{k} \alpha_k \, f\left(\sum_{j=0}^{j} \theta_{ik} X_{jt} \right) \right) \right]^2 \quad (7)$$

The minimization will be accomplished by choosing specific α_k and θ_{jk} where convergence is achieved.

Note that neural network typically requires three different data sets; 1) training sample is required for the initial estimation of parameters. In our model, we let the network to use 70 percent of actual GDP data set for training (base model). 2) testing sample is required to verify the accuracy of prediction obtained from trained model. The number of hidden neurons is determined according to the performance of testing sample model (saturated model). 3) estimating sample is required whether the model is used in prediction (output).

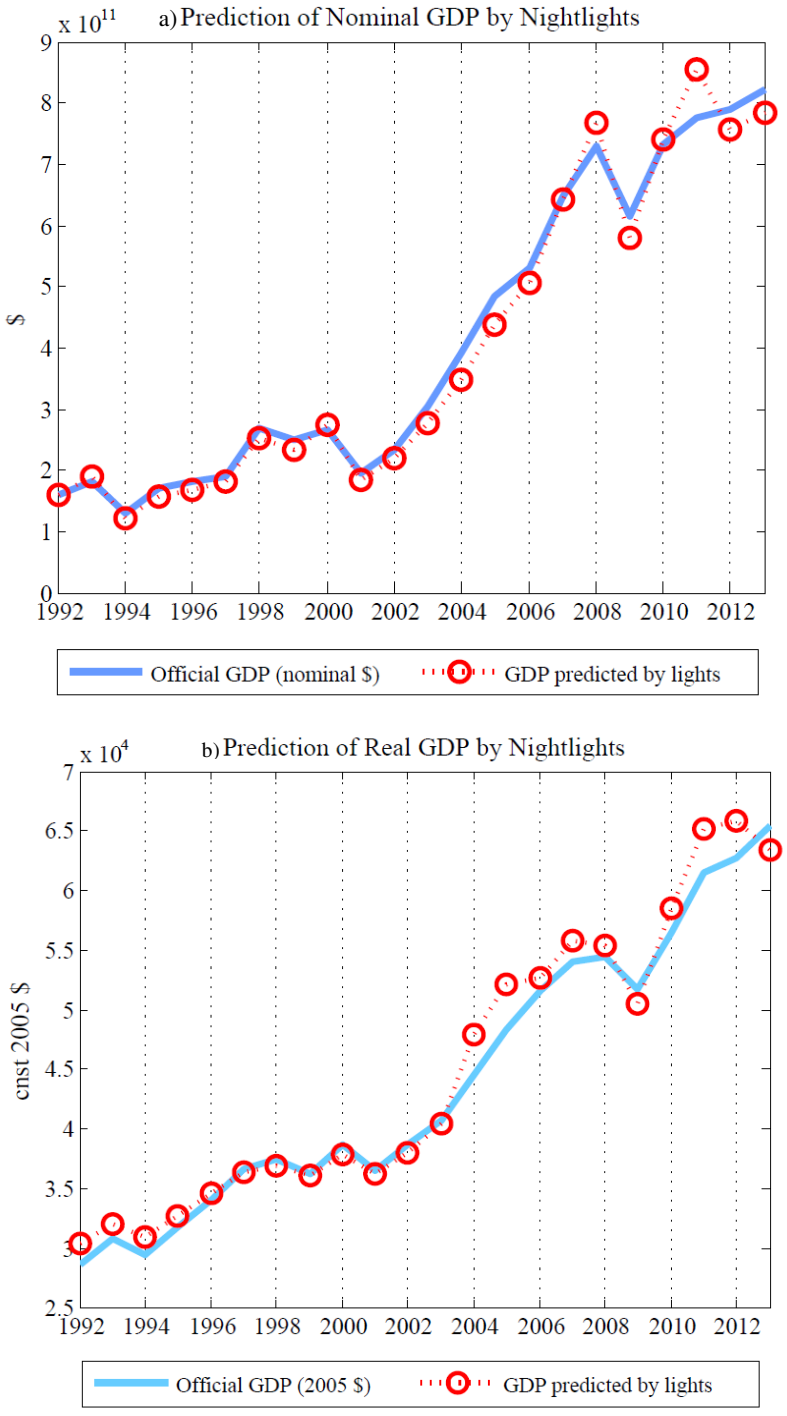
Figure 5 Correlation between base model and predicted model, real and current GDP of Turkey



Note: For the prediction of non-linear parameter, we use 70 percent of data set as testing-sample

Figure 5 shows correlation between estimated and original real and current GDPs for base and overall models. As seen in Figure 5, the network is more successful to estimate real GDP. Figure 6a and 6b show the simulation of estimated nominal and real GDP of Turkey between 1992 and 2013. Since the model is a learning machine with six network parameters, we expect overfitting. However, overfitting is not a concern for our methodology.

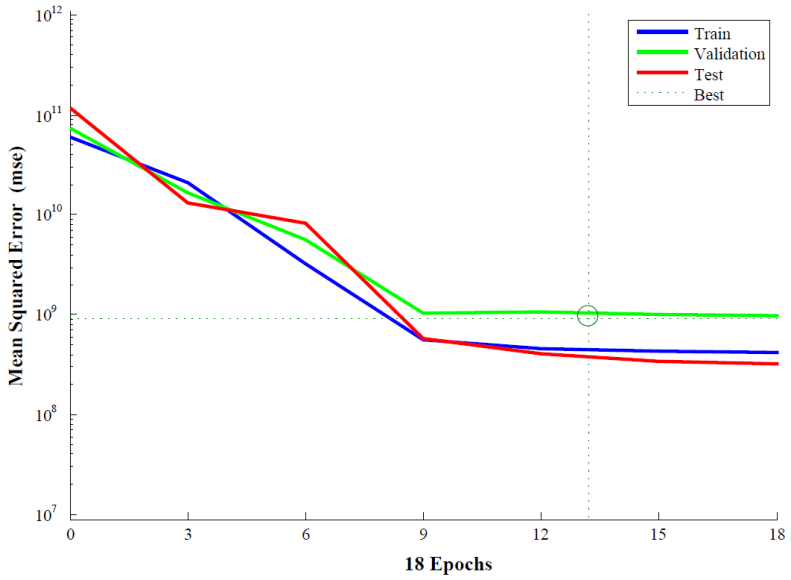
Figure 6 Prediction of nominal and real GDP with nightlights, 1992-2013



Source: World Bank and our calculations

In machine learning models one of the problems which frequently occur is overfitting. Overfitting is likely to occur when too much information or parameters are introduced into a model. In that case, network trains the sample with a very small variance but validation sample will have larger variance due to irrelevant noise in training sample. For one to seek a generalized underlying relationship between variables, overfitting is a problem. However, we propose using the nightlights as a tool to estimate GDP at province level instead of revealing the general relationship between the nightlights and GDP.[16] Therefore, cyclical noises are important for us to estimate the most accurate GDP at provincial level.[17] But, we have to keep a percentage of training sample large enough for the network to learn data rather than memorize. Figure 9 shows that variance of train decreases until 13 iterations while variance of validation decreases to 9 iterations. However, variances of both do not diverge significantly before 13 iterations, where convergence is realized. Figure 9 shows that overfitting do no effect the model's performance in learning of path.

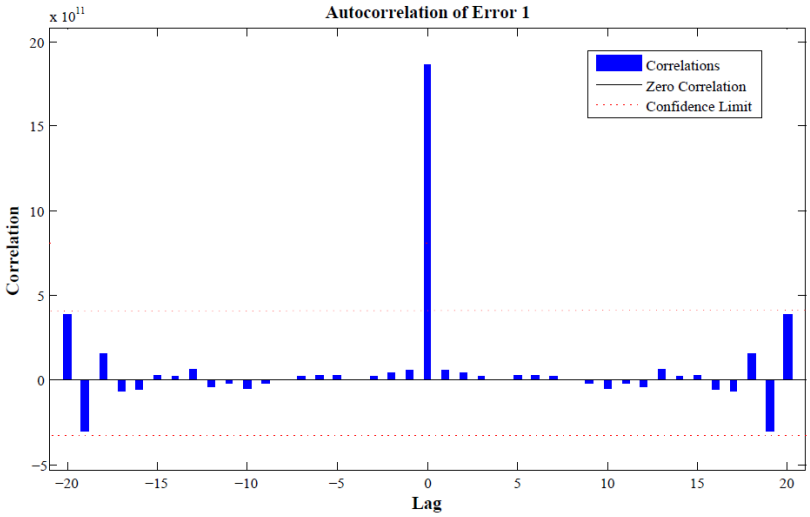
Figure 9: Best Validation Performance



To test our results, we check error autocorrelation.[18] For a perfect model, there should be one nonzero value of autocorrelation function at zero lag, which means that disturbance variances (errors) of the nightlights and GDP are completely uncorrelated (white noise). For our model we cannot say that errors are completely uncorrelated. However, Figure 10 shows that there is no significant correlation between errors within the confidence limit.

[16] We examine overfitting problem for the model which is developed to estimate real GDP
[17] GDP itself has cyclical component.
[18] We check autocorrelation of errors for the model which is developed to estimate real GDP

Figure 10: Autocorrelation of Error



Estimation of GPP with Nightlights

After prediction of Turkey's real and current GDP in order to check the structural validity of the model, we estimate Gross Provincial Product (GPP) with the same method. First, we filter nightlights series of each province with signal processing to clear distortions.

The latest version of GPP was published by TurkStat in 2001. Second, we thus take 2001 GPP as a base year. We normalize the provincial nightlights in 2001 to 100, and simply multiply the proportional growth of provincial nightlights with GPP levels (constant 1987 TL) for the period between 1992 and 2013. However, we know that these series, obtained by a simple method of calculus, do not represent a proper estimation due to a nonlinear relationship between real GDP and nightlights. Third, we re-estimate the provincial nightlights series with the nonlinear network parameters (initial parameters) obtained from the estimation of real GDP. However, we cannot treat each province as if they have same features in terms of economic and geographical conditions. In line with this approach, we put an extra hidden layer without changing the number of hidden neurons. By doing so, the networks built for each province becomes multi-layered. This time, critical values of parameters which activate the neurons are also determined by province-specific conditions within another internal and hidden layer.

Consequently, we obtain the GPP series at constant 1987 TL prices between 1992 and 2013. Then, we convert the series into 2005 constant dollar prices for international comparison (see. Data Appendix). It is also important to mention that there is 34.64 percent gap between Turkey's real GDP and summation of official GPP for the year 2001.[19] We think that this gap results from the error in

[19] Both are at constant 1987 TL prices

statistical recording of public spending on province base.[20] After the estimation of the provincial series, we compare the summation with Turkey's real GDP to see whether the gap has disappeared. The results are satisfactory.

For the purpose of providing further results we also estimate the GDP per capita by province. Since population statistics of provinces are not continuous between 1992 and 2013, we use backward projection from 2007 to 1992 in the construction of the series. By doing so, we harmonize the statistics between 1992 and 2003 to the statistics from 2007 to 2013 which was collected by totally different method.[21]

Main Findings

İstanbul has the largest economy with 117 billion dollars (constant 2005) in 2013. İzmir and Ankara join respectively with about 52 billion dollars (constant 2005). İstanbul alone constitutes 1:6 of Turkey's real GDP in 2013. Ankara, İzmir and İstanbul together constitute 4:10 of total real GDP in the same year. The province of Ardahan has the smallest economy with 300 million dollars (constant 2005). The smallest economies, following Ardahan, are respectively Bayburt, Tunceli, Hakkari and Iğdır (Data Appendix Table 1). We observe that Turkish provinces having higher level of GPP locates in western and southwestern regions of Turkey while GPP levels decrease through eastern and northeastern regions in selected years (Figure 11). It is noteworthy that provinces placing in upper-ten ranks in terms of GPP are relatively industrialized cities.

Analyzing the results in detail, one can see growth trends of the provinces considerably resemble those of Turkey between 1992 and 2013. Most of the provinces represent recovery after 2008 global crisis, but the recoveries of some provinces after 2001 crisis are more pronounced compared to post-2008 (Data Appendix Table 1). Surprisingly, the provinces performing better after the crises in 2001 and 2008 are not İstanbul, Ankara or İzmir. Moreover, İstanbul was the most adversely affected province due to the 2008 global crisis. Real GDP of İstanbul contracted 6.8 percent from 2008 to 2009. After the deep recession in 2009, the slowest recovery also occurred in İstanbul. The least affected province by 2008 global crisis was Hatay. Hatay's economy only contracted by 0.4 percent from 2008 to 2009. In the period between 2001 and 2013, Hatay's economy experienced the largest expansion, 146 percent. It is noteworthy that the provinces which recently gained provincial administration status, Yalova, Düzce and Osmaniye, are among the top-ten provinces, economies of which expended the most in the period between 2001 and 2013.[22] 49 of 81 provinces grew more than Turkey's average in

[20] Such worrying errors also exist for the other years between 1992 and 2001

[21] TurkStat started to use Residence-based Registration System after 2007. Therefore, there is a discrepancy between 1992-2003 series and in terms of population level by province. We re-calculate the population between 1992 and 2007 within 95-percent confidence interval.

[22] Yalova, Osmaniye and Düzce gained province status respectively in 1995, 1996, and 1999.

the period between 2001 and 2013; 32 of them, including İstanbul and Kocaeli, grew less than the average in the same period.

We expand the scope of the results, and estimate the GDP per capita by province level. Yalova has the highest level of GPP per capita with around 20,000 dollars (constant 2005) in 2013. For the same year Kocaeli and Bilecik follows Yalova respectively with about 17, 000 dollars and 15, 000 dollars. On the other hand, Şırnak, Hakkari and Ağri have the lowest level of GPP per capita levels below 2,000 dollars in 2013.

We see the similar picture for GDP per capita by province in terms of regional distribution. Eastern and southeastern regions have considerably lower levels of GPP per capita compared to Western and northwestern regions of Turkey such that GPP of Yalova which locates in Marmara Region is 20-fold of GPP per capita of Şırnak in southeastern Anatolia.

Another string point is about the relatively developed western cities of Turkey attracting internal migration like İstanbul and Antalya. Those provinces fell behind in terms of GPP per capita in 2000s. We see from the results that İstanbul dropped to 15th place to 36th place in ranking from 1992 to 2013 while Antalya fall from 8th to 32nd place. Moreover, İstanbul has the lowest (minus) annual average growth rate of GPP per capita which is just below zero percent between 2008 and 2013. Kocaeli and Tekirdağ also show very low growth rate for the same period even though they have high levels of GPP in 2013.

Conclusion

The concept of how Turkey has experienced an economic alteration in provincial base has stayed vogue especially since the 2001-crisis. There has been no available data or a reliable proxy to measure the magnitude of the provincial economies of Turkey for a while. This study aims to remove the gap in the literature of regional development and growth in Turkey by using different data source, i.e. nightlights, and an algorithm allowing estimating the parameters of a complex system, i.e. neural network. Due to limited data sources in regional level, we estimate gross provincial product with a single independent variable which is nightlights and six hidden variable introduced in the autoregressive nonlinear model. We prefer to treat nightlights series as a referee variable in order to find the closest levels of GPP rather than understanding the underlying relationship between the gross production and the intensity of illumination which has been already indicated in the literature. After testing the validity of the model for the estimation of GDP, we estimate the gross provincial products.

We re-generate the GPP series from 1992 to 2001 while newly constructing the series from 2002 to 2013. The results show that our estimates eliminate the discrepancy between the summation of gross

provincial products and Turkey's GDP which were published by TurkStat for the period between 1992 and 2001.

According to our results, İstanbul has the highest level of gross product in 2013, where İzmir and Ankara join respectively. Another finding is that the industrial economies like Kocaeli and İstanbul affiliated with global economy are relatively more responsive to the global crisis. We also observe that the growth rates of these industrial economies have slowed down over years since 2001 while some of Anatolian cities have grown at higher speeds. The results also show that the regional unbalance of GDP per capita by province exists in Turkey. The cities in western part of the Country have higher level of GPP per capita than the cities in eastern part. On the other hand, industrialized provinces exposed to large internal population movements such as İstanbul, Antalya, Tekirdağ and Kocaeli experience lower rate of GPP growth in 2000s.

References

Bundervoet, T., Maiyo, L., & Sanghi, A. (2015). Bright Lights, Big Cities (No. 22922). The World Bank.

Chen, X., & Nordhaus, W. D. (2011). Using luminosity data as a proxy for economic statistics. Proceedings of the National Academy of Sciences, 108 (21), 8589-8594.

Doll, C. N., Muller, J. P., & Morley, J. G. (2006). Mapping regional economic activity from night-time light satellite imagery. Ecological Economics, 57(1), 75-92.

Ebener, S., Murray, C., Tandon, A., & Elvidge, C. C. (2005). From wealth to health: modelling the distribution of income per capita at the sub-national level using night-time light imagery. *International Journal of health Geographics*, *4*(1), 1.

Feng, L., & Zhang, J. (2014). Application of artificial neural networks in tendency forecasting of economic growth. *Economic Modelling*, *40*, 76-80.

Fierz-Schmidhauser, R. , Zieger P. , Wehrle G. , Jefferson A. , Ogren J. A. , Baltensperger U. , and Weingartner, E. (2010). Measurement of relative humidity dependent light scattering of aerosols. Atmospheric Measurements Techniques

Forbes, D. J. (2005). Statistical Correlation between Economic Activity and.Urban Systems, 29, 179-95.

Ghosh, T., Anderson, S. J., Elvidge, C. D., & Sutton, P. C. (2013). Using nighttime satellite imagery as a proxy measure of human well-being. *Sustainability*, *5*(12), 4988-5019.

Henderson, J. V., Storeygard, A., & Weil, D. N. (2012). Measuring economic growth from outer space. The American Economic Review, 102(2), 994-1028.

Herbrich., R.,Keilbach., M, Graepel., T., Bollmann–Sdorra, P., and Obermayer, K. (1999). Neural Networks in Economics: Background, Applications, and New Developments. Microsoft

Kuan, C. M., & White, H. (1994). Artificial neural networks: an econometric perspective∗. *Econometric Reviews*, *13*(1), 1-91.

Maasoumi, E., Khotanzed, A., & Abaye, A. (1994). Artificial neural networks for some macroeconomic series: a first report. *Econometric Reviews*, *13*(1), 105-122.

Mellander, C., Lobo, J., Stolarick, K., & Matheson, Z. (2015). Night-Time Light Data: A Good Proxy Measure for Economic Activity?. *PloS one*, *10*(10), e0139779.

Narayan, P. K., & Prasad, A. (2008). Electricity consumption–real GDP causality nexus: Evidence from a bootstrapped causality test for 30 OECD countries. Energy Policy, 36(2), 910-918.

Pinkovskiy, M., & Sala-i-Martin, X. (2014). *Lights, Camera,... Income!: Estimating Poverty Using National Accounts, Survey Means, and Lights* (No. w19831). National Bureau of Economic Research.

Shannon, C. E., & Weaver, W. (1993). Information theory. *Encyclopedia Britan*.

Sokolov-Mladenović, S., Milovančević, M., Mladenović, I., & Alizamir, M. (2016). Economic growth forecasting by artificial neural network with extreme learning machine based on trade, import and export parameters. *Computers in Human Behavior*, *65*, 43-45.

Sutton, P. C., Elvidge, C. D., & Ghosh, T. (2007). Estimation of gross domestic product at sub-national scales using nighttime satellite imagery. *International Journal of Ecological Economics & Statistics*, *8*(S07), 5-21.

Tkacz, G., & Hu, S. (1999). Forecasting GDP growth using artificial neural networks. Bank of Canada.

White, H. (1992). Artificial neural networks: approximation and learning theory. Blackwell Publishers, Inc..

Wu, J., Wang, Z., Li, W., & Peng, J. (2013). Exploring factors affecting the relationship between light consumption and GDP based on DMSP/OLS nighttime satellite imagery. *Remote Sensing of Environment*, *134*, 111-119.

Figure 11 GDP (constant 2005 $) by NUTS3 in selected years

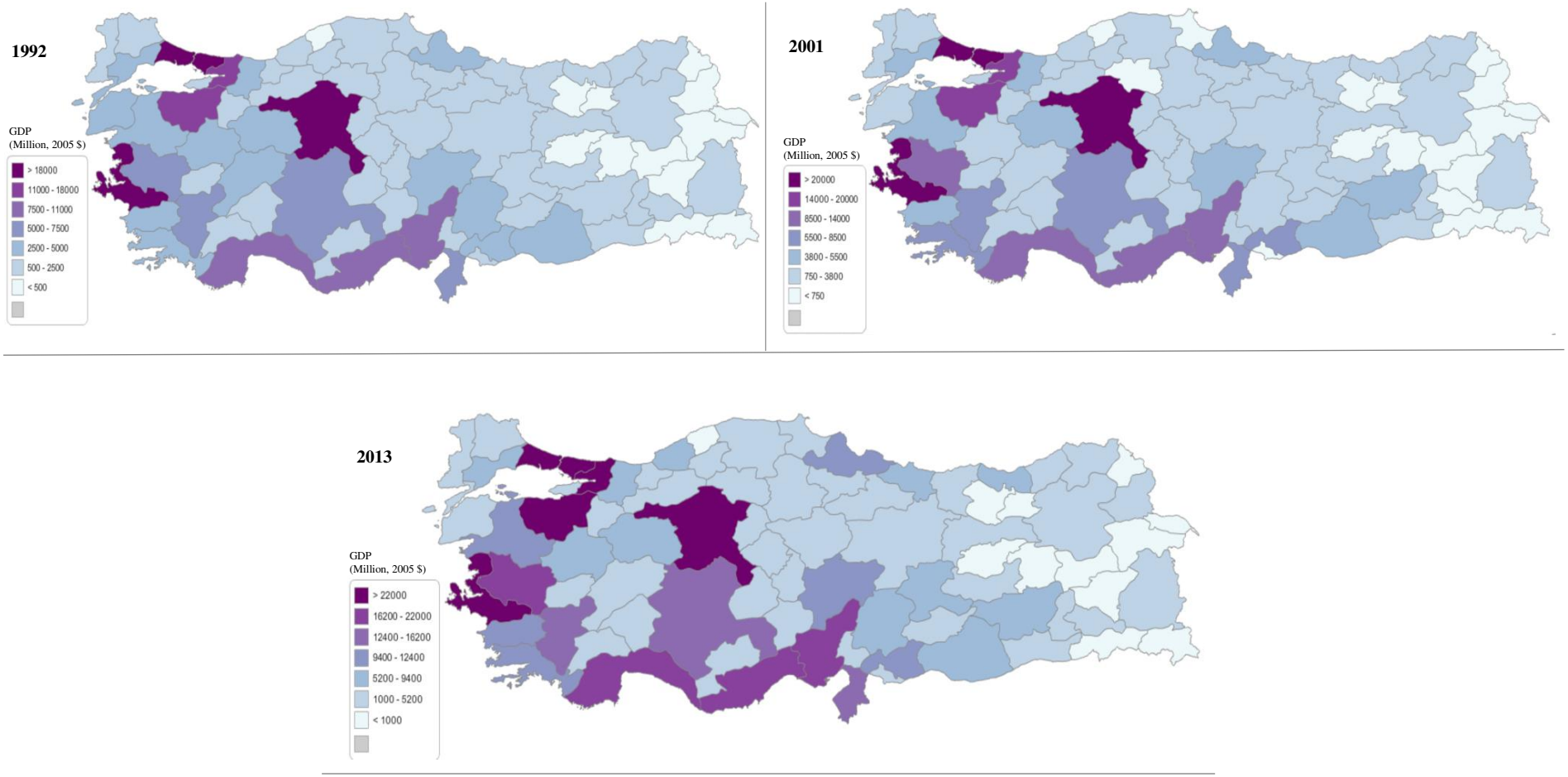


Figure 12 GDP per capita (constant 2005 $) by NUTS3 in selected years

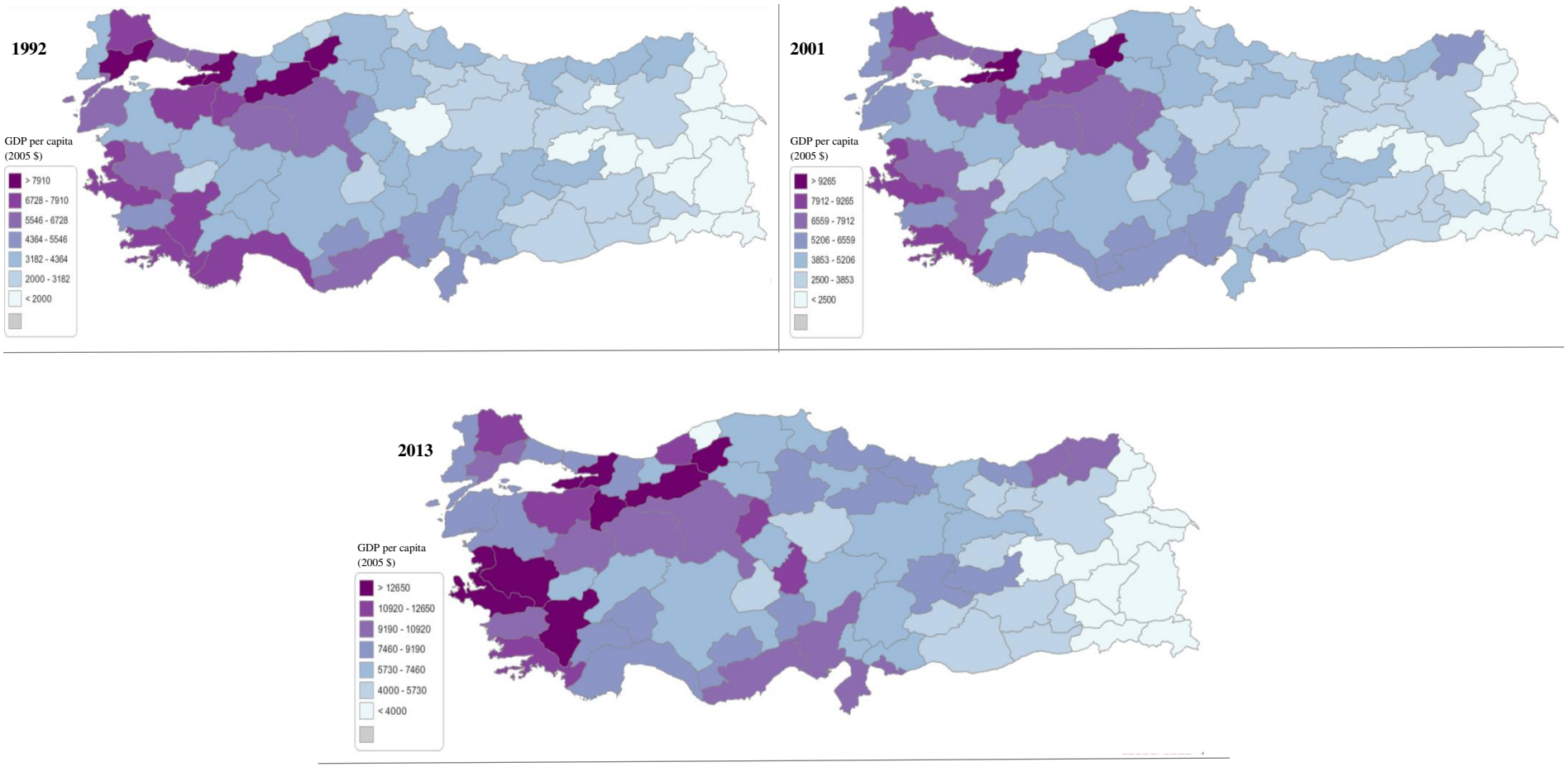


Table 1 GDP estimates by province level

Million (2005$)	YEAR																					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
PROVINCE																						
Adana	7986	8870	8674	9564	10489	11310	11354	10996	11497	10585	11273	11943	13274	14551	15395	16017	16421	15569	16882	18613	18906	20352
Adıyaman	1558	1519	1411	1492	1573	1672	1679	1626	1692	1569	1595	1637	1772	1892	2062	2147	2185	2098	2347	2575	2687	2822
Afyon	2530	2404	2203	2288	2416	2588	2643	2567	2709	2548	2694	2821	3078	3299	3541	3629	3721	3601	4131	4548	4875	4912
Ağrı	409	451	447	498	546	600	605	592	619	582	632	664	713	767	820	833	811	778	836	887	925	936
Aksaray	773	783	747	810	869	939	952	915	962	903	976	1013	1108	1157	1277	1315	1350	1281	1427	1525	1580	1655
Amasya	969	995	959	1045	1128	1213	1244	1191	1272	1194	1280	1358	1492	1581	1762	1806	1808	1692	1880	2029	2120	2266
Ankara	19017	22874	21169	23066	24597	26037	26974	26956	29111	28104	30657	32161	36061	39014	41730	44133	44142	42105	46803	50521	52261	51287
Antalya	9094	8840	8348	8946	9534	10223	10445	10021	10405	9810	10187	10906	12046	13178	14049	14671	14809	13945	15372	16934	17285	18452
Ardahan	149	159	158	177	194	214	220	209	223	211	221	227	238	258	271	281	274	263	280	295	302	300
Artvin	591	686	693	793	884	966	992	969	1015	954	1039	1077	1169	1239	1335	1385	1385	1304	1414	1525	1566	1696
Aydın	4033	4686	4402	4771	5095	5378	5432	5251	5584	5195	5361	5643	6171	6748	7215	7583	7819	7555	8400	9446	9858	10678
Balıkesir	4232	4897	4602	5071	5402	5694	5771	5515	5744	5290	5444	5716	6155	6614	7166	7463	7638	7324	7988	8831	9048	9945
Bartın	367	356	328	342	360	386	400	386	413	388	428	433	462	484	529	545	551	528	592	647	685	748
Batman	700	780	797	894	976	1083	1130	1094	1195	1180	1289	1370	1526	1639	1762	1806	1838	1719	1839	2015	2039	2307
Bayburt	134	145	145	161	175	191	195	187	201	193	213	222	238	255	271	279	273	261	291	319	338	362
Bilecik	1481	1620	1528	1666	1791	1870	1908	1826	1917	1776	1856	1930	2067	2244	2427	2522	2621	2532	2841	3107	3228	3270
Bingöl	309	329	320	350	373	403	413	397	426	402	440	462	499	532	577	593	577	539	581	613	627	655
Bitlis	391	452	427	475	504	531	537	510	524	478	529	557	608	651	702	724	719	688	754	823	859	916
Bolu	2270	2246	2087	2190	2287	2424	2489	2368	2502	2316	2392	2485	2658	2830	3092	3220	3254	3073	3431	3695	3781	3921
Burdur	1012	1092	1031	1116	1219	1293	1324	1272	1354	1248	1285	1352	1472	1589	1712	1789	1853	1787	1990	2197	2255	2347
Bursa	14651	13885	12765	13266	14028	15079	15553	15095	16148	15265	16222	17250	18652	20595	21946	23174	23954	23286	25529	28269	28899	31071
Çanakkale	2789	2676	2494	2603	2748	2935	3004	2865	2993	2799	2887	3011	3218	3433	3691	3800	3827	3615	3884	4170	4200	4518
Çankırı	548	647	594	637	673	705	732	716	769	729	775	801	870	918	1014	1046	1050	983	1125	1205	1272	1271
Çorum	1926	2178	2037	2190	2329	2466	2511	2452	2618	2481	2667	2807	3062	3215	3541	3612	3601	3398	3788	4017	4159	4125
Denizli	5392	5485	5084	5381	5692	6046	6229	5966	6373	5907	6283	6549	7135	7652	8230	8571	8874	8570	9649	10846	11411	12483
Diyarbakır	2414	2674	2674	3000	3281	3594	3818	3793	4072	4059	4399	4678	5223	5626	6068	6117	6086	5619	6012	6508	6698	7259
Düzce	891	970	895	959	1023	1081	1101	1066	1124	1039	1148	1162	1261	1335	1473	1590	1687	1611	1812	1987	2012	2157

Table 1 GDP estimates by province level (continued)

Million (2005 $)	YEAR																					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
PROVINCE																						
Edirne	1353	1542	1583	1786	1933	2115	2146	2051	2187	2110	2076	2178	2285	2478	2643	2777	2832	2775	2965	3191	3173	3243
Elazığ	1554	1576	1511	1614	1730	1853	1941	1875	2015	1940	2131	2237	2456	2629	2843	2931	2938	2789	3088	3345	3484	3663
Erzincan	574	607	598	660	720	788	797	767	806	757	833	877	950	1006	1094	1125	1109	1053	1167	1255	1310	1370
Erzurum	1547	1765	1630	1771	1882	1989	2012	1955	2053	1935	2076	2164	2316	2512	2660	2760	2727	2667	2896	3135	3268	3324
Eskişehir	3576	3802	3805	4213	4593	5023	5111	4926	5228	5017	5210	5424	5907	6296	6833	7071	7141	6769	7563	8089	8386	8276
Gaziantep	4381	4485	4394	4789	5211	5675	5838	5606	5937	5593	5911	6198	6886	7585	8113	8520	8859	8529	9416	10496	10884	11465
Giresun	1523	1553	1444	1540	1683	1812	1872	1796	1902	1734	1938	2032	2207	2327	2527	2607	2621	2464	2704	2883	2957	3121
Gümüşhane	293	314	309	344	377	413	419	407	431	409	439	460	496	529	574	596	600	575	638	689	709	729
Hakkari	246	239	222	230	242	257	268	258	281	264	287	301	330	352	379	387	383	360	390	416	431	448
Hatay	5294	5108	4783	4952	5224	5647	5919	5653	6142	5743	6338	6637	7430	8154	8728	9423	10094	10046	11117	12623	13059	14111
Iğdır	242	266	250	270	285	304	307	292	312	294	305	319	350	378	406	424	432	408	443	483	492	524
Isparta	1459	1565	1509	1626	1729	1864	1922	1847	1970	1849	2117	2281	2518	2796	2976	3135	3119	2951	3157	3443	3498	3718
İstanbul	59009	66530	61462	65928	70044	74958	77152	75835	82189	78320	80972	85812	93107	101972	106237	112291	108321	100863	106646	114198	112895	116956
İzmir	21536	23283	22794	24752	26412	28584	29247	27894	29642	27807	29282	30992	34041	38009	39901	42429	43238	41834	45156	49682	50236	51558
K. Maraş	3664	3515	3311	3389	3546	3815	3856	3660	3919	3647	3849	3976	4275	4554	4954	5146	5198	4942	5518	6060	6347	6879
Karabük	1694	1748	1677	1794	1967	2110	2163	2070	2208	2041	2172	2281	2471	2595	2826	2880	2878	2667	2882	3023	3038	3121
Karaman	918	1024	994	1080	1179	1255	1279	1232	1328	1241	1320	1386	1483	1619	1712	1755	1717	1665	1798	1917	1985	1954
Kars	465	531	499	535	576	616	630	617	675	633	660	681	729	765	840	862	853	796	894	956	998	1041
Kastamonu	1309	1276	1256	1331	1435	1554	1601	1490	1588	1523	1718	1827	1990	2110	2261	2300	2260	2126	2333	2477	2566	2646
Kayseri	3218	3546	3551	3969	4309	4705	4747	4518	4696	4419	4674	4956	5534	6095	6634	7003	7292	6986	7631	8509	8751	9457
Kırıkkale	1475	1643	1548	1666	1785	1929	1957	1894	2041	1914	2145	2193	2409	2512	2810	2914	2938	2816	3157	3317	3484	3392
Kırklareli	2256	2301	2188	2349	2568	2788	2925	2827	3036	2881	2873	2968	3109	3315	3608	3783	3857	3737	4008	4268	4213	4315
Kırşehir	706	744	722	768	816	881	905	861	923	876	943	988	1087	1142	1264	1286	1294	1240	1386	1483	1553	1547
Kilis	538	536	521	546	586	638	646	615	665	628	712	754	835	916	973	1026	1038	991	1076	1174	1194	1243
Kocaeli	13890	14689	14082	15038	16244	17490	17931	17018	18054	16706	18146	19004	20829	21935	23941	24537	24406	23016	25117	26730	27549	28221
Konya	6177	6459	6216	6642	7141	7706	7883	7478	8022	7538	7699	8143	8813	9427	10275	10616	10847	10438	11804	12917	13504	13704
Kütahya	2620	2514	2406	2496	2658	2886	2898	2762	2957	2760	3093	3260	3606	3885	4206	4362	4399	4183	4625	5038	5253	5509

Table 1 GDP estimates by province level (continued)

Million (2005 $)	YEAR																					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
PROVINCE																						
Malatya	2336	2664	2523	2727	2921	3086	3129	3000	3227	3009	3121	3333	3668	3985	4273	4447	4565	4373	4763	5262	5361	5699
Manisa	6983	7995	8023	8877	9607	10363	10556	10030	10614	9977	10957	11607	12824	13780	14896	15268	15367	14486	15921	17214	17826	18588
Mardin	1418	1478	1462	1575	1750	1908	1919	1850	2003	1877	1993	2120	2363	2545	2760	2829	2878	2694	2882	3093	3106	3188
Mersin	8121	8787	8370	9024	9657	10285	10423	9965	10540	9783	10132	10569	11564	12726	13816	14603	15216	14757	16196	17633	18096	18045
Muğla	4331	4460	4318	4650	5074	5523	5665	5440	5835	5501	5691	5964	6528	7066	7565	7855	7955	7582	8249	9097	9399	10122
Muş	418	445	439	480	532	579	579	551	587	544	582	611	654	697	750	758	734	696	743	784	810	837
Nevşehir	1018	1168	1214	1386	1534	1672	1705	1631	1709	1640	2007	2164	2425	2629	2793	2795	2787	2654	2896	3107	3241	3297
Niğde	1160	1213	1200	1297	1413	1542	1563	1482	1561	1444	1608	1681	1850	1959	2128	2215	2260	2180	2457	2729	2890	3121
Ordu	1862	2049	2077	2321	2544	2813	2863	2708	2857	2700	2983	3128	3451	3684	3990	4141	4188	3926	4378	4828	5010	5509
Osmaniye	1180	1111	1054	1088	1173	1261	1288	1228	1321	1243	1321	1400	1554	1708	1829	1943	2094	2071	2306	2603	2701	2890
Rize	1251	1354	1315	1421	1562	1681	1672	1588	1681	1528	1732	1798	1959	2060	2228	2317	2350	2247	2484	2701	2809	3039
Sakarya	3089	3230	3204	3462	3798	4158	4161	3969	4208	3894	4317	4488	4896	5325	5786	6168	6478	6268	6931	7613	7724	8154
Samsun	3746	3895	3908	4297	4811	5303	5390	5225	5622	5293	5953	6140	6699	6966	7714	8060	8120	7609	8441	9069	9291	10054
Siirt	567	602	606	664	717	785	790	740	771	718	746	785	855	916	989	1007	1014	949	1018	1082	1090	1123
Sinop	527	621	601	658	710	765	777	742	799	745	800	846	937	1013	1099	1133	1148	1068	1160	1269	1295	1425
Sivas	1693	1840	1817	1995	2224	2429	2472	2400	2587	2410	2433	2514	2658	2780	3076	3169	3239	3087	3459	3751	3862	4084
Şanlıurfa	2996	3175	3190	3497	3868	4205	4200	4041	4343	4100	4440	4663	5160	5542	5985	6202	6297	5916	6396	6885	6955	7300
Şırnak	337	383	379	418	451	478	475	446	467	435	476	503	549	586	643	666	658	624	685	728	749	754
Tekirdağ	4052	3934	3822	4028	4395	4851	4931	4748	5123	4828	4757	5029	5300	5827	6235	6526	6734	6553	7082	7725	7711	7964
Tokat	1735	1839	1857	2071	2318	2543	2601	2508	2671	2528	2763	2880	3124	3282	3641	3783	3827	3628	3994	4254	4348	4545
Trabzon	2428	2693	2700	3009	3249	3542	3540	3329	3432	3219	3629	3757	4104	4337	4688	4890	5047	4806	5353	5864	6036	6526
Tunceli	132	145	150	171	190	213	217	206	216	203	223	234	256	276	299	315	316	302	334	357	365	366
Uşak	921	943	939	1013	1119	1232	1241	1187	1276	1185	1222	1297	1422	1557	1679	1772	1898	1855	2127	2365	2458	2456
Van	1109	1216	1259	1402	1540	1668	1648	1532	1599	1493	1650	1725	1865	1993	2145	2198	2185	2085	2265	2463	2566	2754
Yalova	1471	1576	1541	1670	1808	1940	1963	1867	1971	1869	2090	2164	2332	2528	2710	2846	3058	3019	3335	3751	3849	4287
Yozgat	1166	1236	1233	1336	1461	1582	1579	1495	1573	1462	1595	1667	1803	1859	2095	2096	2064	1936	2100	2169	2242	2239
Zonguldak	2169	2344	2377	2646	2923	3226	3288	3139	3321	3142	3712	3772	4072	4169	4589	4771	4941	4901	5682	6326	6860	7449
TURKEY	**286347**	**308256**	**293866**	**317018**	**340413**	**366208**	**374661**	**362052**	**386579**	**364554**	**387025**	**407402**	**445547**	**482980**	**516274**	**540377**	**543937**	**517687**	**565092**	**614666**	**627742**	**654061**

Table 2 GDP per capita estimates by province level

(2005 $)	YEAR																					
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
PROVINCE																						
Adana	4577	5037	4880	5331	5792	6187	6153	5904	6116	5578	5886	6178	6803	7388	7744	7982	8108	7616	8181	8936	8992	9590
Adıyaman	2829	2747	2542	2678	2813	2978	2980	2876	2980	2754	2788	2852	3075	3271	3551	3684	3735	3574	3982	4353	4526	4735
Afyon	3671	3483	3188	3308	3488	3733	3807	3694	3894	3657	3863	4040	4402	4713	5053	5173	5298	5121	5868	6453	6908	6952
Ağrı	810	891	880	977	1067	1168	1176	1145	1193	1118	1211	1267	1358	1454	1549	1570	1522	1457	1559	1649	1713	1728
Aksaray	2310	2326	2206	2377	2535	2723	2745	2622	2740	2557	2747	2834	3082	3199	3509	3593	3665	3457	3829	4068	4188	4361
Amasya	2852	2936	2836	3097	3349	3610	3711	3559	3811	3584	3851	4095	4510	4788	5350	5495	5513	5172	5759	6229	6523	6987
Ankara	5596	6609	6006	6426	6729	6994	7115	6982	7404	7019	7518	7744	8527	9058	9514	9880	9704	9089	9921	10516	10681	10293
Antalya	7617	7207	6625	6911	7169	7482	7442	6949	7024	6446	6515	6789	7300	7773	8066	8199	8053	7379	7915	8484	8426	8753
Ardahan	1070	1157	1164	1327	1470	1643	1716	1653	1788	1718	1829	1899	2022	2223	2370	2494	2467	2397	2592	2773	2881	2897
Artvin	3526	4091	4135	4729	5270	5759	5909	5776	6046	5683	6189	6414	6958	7374	7944	8241	8235	7753	8406	9068	9311	10079
Aydın	5081	5836	5418	5803	6125	6389	6378	6093	6403	5887	6005	6246	6751	7296	7710	8007	8160	7792	8562	9516	9815	10507
Balıkesir	4176	4801	4482	4907	5193	5437	5475	5198	5378	4920	5031	5247	5614	5992	6450	6674	6785	6464	7004	7692	7829	8549
Bartın	2178	2098	1926	1998	2088	2229	2302	2205	2349	2195	2408	2425	2574	2684	2918	2994	3012	2870	3199	3478	3665	3981
Batman	2001	2183	2188	2405	2575	2798	2863	2716	2910	2817	3016	3140	3430	3611	3805	3823	3813	3496	3666	3937	3905	4330
Bayburt	1818	1967	1963	2176	2357	2560	2616	2493	2678	2557	2820	2933	3130	3341	3547	3648	3550	3392	3767	4119	4346	4651
Bilecik	7786	8476	7960	8639	9245	9605	9757	9296	9713	8959	9318	9644	10285	11112	11966	12376	12805	12311	13752	14970	15480	15612
Bingöl	1357	1437	1386	1508	1596	1711	1744	1665	1773	1664	1808	1886	2024	2145	2309	2357	2279	2114	2262	2373	2409	2503
Bitlis	1269	1460	1375	1522	1611	1687	1701	1609	1647	1496	1648	1727	1877	2003	2149	2209	2183	2080	2270	2468	2565	2724
Bolu	9488	9312	8581	8933	9250	9727	9907	9347	9797	8993	9214	9495	10073	10636	11529	11909	11936	11181	12382	13224	13424	13808
Burdur	4221	4542	4275	4614	5023	5312	5422	5192	5508	5062	5198	5451	5915	6366	6839	7123	7354	7071	7849	8639	8840	9172
Bursa	7729	7203	6511	6654	6919	7313	7417	7078	7446	6921	7232	7562	8041	8730	9147	9498	9654	9228	9948	10832	10889	11511
Çanakkale	6637	6314	5836	6041	6325	6699	6800	6432	6663	6181	6321	6539	6929	7330	7817	7981	7970	7467	7957	8472	8461	9027
Çankırı	3361	3951	3608	3855	4059	4230	4373	4259	4553	4299	4553	4684	5068	5319	5853	6012	6008	5600	6384	6806	7154	7119
Çorum	3245	3687	3466	3747	4004	4261	4361	4280	4594	4376	4728	5002	5484	5788	6408	6570	6582	6244	6996	7456	7760	7735
Denizli	6907	6956	6384	6688	7005	7366	7514	7124	7534	6914	7280	7513	8103	8604	9162	9446	9682	9258	10319	11484	11962	12954
Diyarbakır	2031	2218	2189	2422	2612	2822	2957	2898	3069	3017	3226	3383	3726	3959	4212	4188	4110	3742	3950	4217	4281	4577
Düzce	3298	3547	3237	3424	3610	3771	3792	3627	3779	3454	3770	3771	4042	4228	4611	4917	5156	4865	5406	5859	5861	6209
Edirne	3501	3983	4082	4596	4967	5426	5497	5243	5583	5375	5280	5531	5793	6272	6679	7006	7132	6977	7440	7994	7937	8097

Table 2 GDP per capita estimates by province level (continued)

(2005 $)	YEAR																					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
PROVINCE																						
Elazığ	4019	4071	3897	4154	4445	4755	4970	4795	5143	4943	5420	5680	6226	6653	7183	7356	7326	6909	7600	8178	8463	8840
Erzincan	2886	3040	2982	3274	3551	3869	3898	3732	3901	3650	3995	4187	4512	4758	5147	5267	5168	4886	5386	5768	5990	6237
Erzurum	2117	2404	2210	2390	2527	2658	2675	2587	2704	2537	2708	2809	2993	3230	3373	3511	3480	3415	3720	4040	4225	4312
Eskişehir	6132	6426	6338	6917	7433	8011	8035	7632	7983	7551	7729	7929	8511	8941	9565	9756	9710	9072	9989	10530	10760	10466
Gaziantep	3994	3994	3821	4069	4324	4601	4622	4336	4486	4127	4261	4364	4736	5096	5324	5461	5547	5217	5625	6125	6204	6384
Giresun	3783	3846	3569	3797	4139	4445	4582	4386	4634	4213	4699	4914	5325	5602	6067	6244	6264	5873	6430	6839	6999	7367
Gümüşhane	2856	3009	2914	3190	3444	3714	3704	3543	3685	3441	3634	3755	3978	4177	4456	4559	4510	4259	4648	4934	4999	5055
Hakkari	1222	1171	1075	1098	1141	1195	1230	1165	1252	1162	1248	1290	1393	1466	1559	1569	1532	1422	1518	1597	1633	1674
Hatay	4514	4308	3989	4084	4260	4555	4721	4458	4790	4430	4834	5006	5542	6015	6367	6798	7201	7087	7756	8709	8909	9520
Iğdır	1463	1599	1492	1601	1680	1779	1787	1688	1791	1680	1731	1797	1959	2107	2245	2333	2363	2213	2392	2589	2620	2774
Isparta	3501	3754	3619	3895	4142	4462	4598	4418	4710	4417	5055	5443	6007	6667	7092	7468	7424	7023	7508	8183	8310	8828
İstanbul	6046	6703	6089	6422	6708	7059	7143	6904	7357	6893	7007	7302	7790	8389	8593	8931	8471	7755	8062	8489	8251	8405
İzmir	6895	7365	7125	7644	8060	8618	8713	8211	8621	7991	8315	8695	9437	10411	10799	11347	11425	10922	11649	12664	12652	12830
K.Maraş	4220	4010	3740	3792	3928	4185	4190	3938	4177	3849	4023	4116	4382	4623	4981	5123	5125	4825	5336	5803	6020	6461
Karabük	8873	9077	8632	9150	9940	10570	10737	10181	10765	9861	10400	10821	11622	12096	13054	13182	13054	11991	12842	13348	13296	13534
Karaman	4554	5041	4857	5237	5672	5993	6062	5795	6197	5746	6066	6321	6712	7273	7634	7764	7540	7255	7774	8227	8453	8256
Kars	1336	1536	1456	1570	1704	1835	1890	1866	2054	1941	2039	2120	2285	2416	2670	2762	2751	2587	2925	3151	3314	3481
Kastamonu	3840	3729	3657	3863	4150	4475	4595	4261	4524	4322	4858	5147	5583	5898	6298	6383	6248	5855	6403	6773	6989	7180
Kayseri	3485	3782	3729	4104	4387	4716	4684	4390	4492	4163	4335	4526	4976	5396	5783	6011	6162	5813	6252	6864	6950	7396
Kırıkkale	4955	5542	5243	5664	6095	6612	6735	6543	7080	6665	7500	7700	8494	8891	9986	10398	10526	10130	11402	12028	12686	12400
Kırklareli	7241	7350	6957	7437	8093	8749	9136	8793	9400	8881	8817	9066	9454	10038	10874	11351	11521	11113	11866	12581	12363	12604
Kırşehir	3220	3390	3285	3492	3706	3996	4101	3893	4168	3951	4251	4449	4886	5129	5668	5765	5792	5544	6190	6616	6918	6882
Kilis	5340	5267	5066	5253	5576	5997	6011	5664	6054	5660	6346	6650	7279	7901	8300	8660	8668	8187	8794	9492	9546	9832
Kocaeli	13729	14183	13282	13855	14620	15376	15399	14276	14794	13372	14189	14516	15540	15987	17044	17064	16580	15273	16282	16926	17040	17052
Konya	3624	3754	3580	3790	4037	4316	4374	4111	4369	4068	4116	4314	4626	4902	5293	5419	5486	5230	5860	6353	6581	6616
Kütahya	4328	4163	3994	4153	4434	4825	4857	4640	4980	4659	5234	5530	6132	6621	7186	7471	7552	7199	7979	8711	9105	9571
Malatya	3623	4099	3853	4134	4395	4608	4637	4412	4711	4360	4488	4757	5196	5603	5962	6159	6275	5966	6449	7071	7150	7543
Manisa	5699	6493	6483	7138	7687	8251	8363	7907	8326	7787	8510	8970	9861	10545	11342	11567	11585	10867	11884	12785	13174	13670

Table 2 GDP per capita estimates by province level (continued)

(2005 $)	YEAR																					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
PROVINCE																						
Mardin	2121	2196	2156	2305	2543	2751	2748	2629	2827	2630	2772	2926	3238	3463	3728	3793	3830	3560	3781	4028	4016	4092
Mersin	5902	6323	5964	6367	6746	7114	7139	6758	7078	6505	6670	6890	7464	8133	8743	9150	9441	9066	9852	10621	10792	10656
Muğla	7494	7574	7196	7605	8144	8700	8757	8253	8687	8038	8161	8393	9015	9576	10061	10253	10189	9530	10176	11013	11167	11802
Muş	1044	1112	1096	1196	1325	1440	1439	1368	1457	1349	1440	1512	1618	1721	1851	1870	1808	1713	1826	1926	1989	2054
Nevşehir	3782	4328	4486	5109	5639	6131	6232	5949	6214	5948	7262	7807	8727	9436	9999	9978	9926	9425	10260	10978	11422	11589
Niğde	3753	3907	3846	4139	4488	4875	4917	4641	4864	4479	4965	5165	5656	5963	6446	6679	6781	6510	7303	8074	8510	9146
Ordu	2685	2949	2983	3326	3638	4014	4077	3848	4052	3821	4213	4409	4854	5171	5589	5788	5842	5465	6082	6693	6931	7604
Osmaniye	3201	2974	2781	2832	3013	3195	3217	3026	3212	2981	3124	3267	3576	3876	4094	4289	4561	4450	4886	5441	5568	5877
Rize	4224	4550	4403	4736	5181	5552	5500	5200	5482	4962	5598	5786	6275	6570	7075	7328	7399	7045	7753	8393	8690	9361
Sakarya	4602	4743	4636	4937	5338	5760	5680	5340	5580	5088	5559	5696	6124	6564	7029	7385	7644	7289	7944	8599	8598	8946
Samsun	3261	3375	3371	3690	4113	4514	4567	4408	4721	4424	4954	5087	5525	5719	6305	6558	6578	6136	6776	7247	7392	7963
Siirt	2275	2391	2378	2580	2759	2988	2977	2758	2845	2623	2698	2807	3026	3208	3429	3454	3442	3188	3386	3559	3548	3620
Sinop	2782	3271	3158	3444	3705	3977	4026	3837	4116	3824	4097	4320	4769	5138	5556	5711	5768	5350	5790	6317	6425	7046
Sivas	2515	2743	2718	2996	3351	3673	3751	3654	3954	3696	3745	3883	4119	4323	4800	4964	5091	4869	5475	5958	6156	6533
Şanlıurfa	2812	2910	2855	3056	3301	3504	3417	3211	3369	3105	3284	3368	3639	3816	4024	4072	4037	3704	3910	4110	4053	4154
Şırnak	1064	1184	1153	1247	1321	1376	1344	1239	1273	1164	1252	1299	1392	1461	1575	1602	1554	1447	1560	1627	1646	1627
Tekirdağ	8429	7961	7522	7712	8184	8785	8687	8136	8538	7826	7500	7713	7907	8455	8800	8960	8993	8511	8948	9493	9217	9260
Tokat	2597	2766	2807	3146	3538	3901	4009	3885	4158	3955	4344	4549	4960	5236	5837	6094	6195	5903	6530	6990	7179	7541
Trabzon	3487	3850	3845	4268	4589	4983	4960	4644	4769	4455	5002	5157	5610	5904	6357	6604	6787	6437	7140	7789	7986	8599
Tunceli	1635	1786	1851	2099	2334	2607	2645	2508	2620	2459	2686	2814	3077	3306	3571	3752	3755	3574	3938	4202	4282	4290
Uşak	3021	3073	3041	3263	3583	3918	3924	3731	3985	3679	3771	3977	4335	4718	5057	5304	5647	5484	6252	6908	7135	7086
Van	1363	1477	1510	1662	1803	1929	1882	1728	1781	1642	1792	1851	1976	2085	2217	2244	2202	2076	2227	2392	2461	2609
Yalova	12173	12691	12080	12738	13422	14015	13796	12771	13118	12109	13173	13273	13919	14689	15321	15656	16374	15730	16911	18506	18480	20034
Yozgat	1811	1955	1985	2190	2437	2687	2731	2633	2820	2668	2963	3152	3472	3644	4181	4259	4270	4078	4503	4735	4982	5065
Zonguldak	3333	3616	3680	4111	4557	5049	5164	4949	5255	4990	5917	6035	6540	6720	7423	7747	8053	8016	9328	10423	11345	12364
TURKEY	**4714**	**5019**	**4732**	**5049**	**5361**	**5703**	**5768**	**5511**	**5817**	**5423**	**5691**	**5921**	**6399**	**6856**	**7243**	**7492**	**7451**	**7001**	**7557**	**8121**	**8193**	**8433**