Assessing the Spatial and Temporal Variation of Output-Input Elasticities of Agricultural Production in Turkey

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[This version is the preliminary draft]

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9, 2010

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Abstract

This study evaluates the impacts of the Agricultural Reform Implementation Project (ARIP) on Turkey's agricultural market. Using a Turkish province-level data, we estimated an agricultural production function incorporating with a spatially heterogeneous error component to generate the output elasticities with respect to various inputs. This geographically weighted regression model (GWR-SEM) analyzes spatial variation of output-input elasticities and identifies the clusters of high output-input elasticities before and after the implementation of ARIP. Results suggest that the output elasticities with respect to inputs generally improved across the country in the post-ARIP period.

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1. Introduction

Located at the nexus between Europe and Asia, Turkey is the largest producer and exporter of agricultural products in the Near East and North Africa region (IGEME, 2009). The diverse climatological and topographical condition provides a unique environment for a wide variety of agricultural commodities. Turkey dominates the production and export of various fruits, dried fruits, vegetables, and olive oil in the global market and it is also an important supplier of some cereals, such as wheat and barley. In 2005, crop production accounted for 72% of total agricultural output, while livestock products made 22% of the total output (AgCanada, 2008).

Currently, agriculture in Turkey is a slowly modernized sector but remains influential to Turkey's economy, accounting for more than 30 percent of workforce and contributing to about 10 percent of national GDP in 2007 (USDA, 2009). Turkey has about 27 million hectares (ha) of cultivated land and nearly 12 million ha of pastures. Based on the 2001 Agricultural Census, more than 3 million agricultural land holdings are operated by a single household and the national average farm size of in Turkey is less than 6 ha (AgCanada, 2008). This implies that the majority of farm households in Turkey still exercise a low-input less-productivity agricultural operation relying on government's supports.

Historically, agricultural producer supports in Turkey were entirely based on commodity output and focused on variable input subsidies in the eighties and nineties, which has been criticized as biased supports towards richer regions and larger farmers. Sponsored by the International Monetary Fund and the World Bank, the Agricultural Reform and Implementation Project (ARIP) was introduced in 2001 which aims to prompt the liberalization of Turkish agricultural programs. The ARIP represents a new direction in Turkish agricultural policy, whose target is to bring the country more in line with the European Union (EU) agricultural policies and to mitigate the regional economic inequalities between the west and east regions. Under the ARIP, several agricultural policies have been modified. For example, price supports and input subsidies to farmers including fertilizer and pesticide were replaced by a direct income support.

A better understanding of the impact of the implementation of ARIP on the agricultural production is an essential element to evaluating the performance of ARIP. Thus, the objective of this research is to analyze the impact of the implementation of ARIP on agriculture production, focusing particularly on how this impact changes across the country and over time. This analysis is conducted through the estimation of output-input elasticities for agricultural production using geographically weighted regression (GWR) in a Cobb Douglas production function. Because GWR coefficients vary over space, the output-input elasticities also vary over space. The temporal dynamics of the output-input elasticities are analyzed by applying the model to data for output variable (i.e., gross revenue of agricultural production) and input variables (i.e., harvested area, fertilizer utilization, agricultural labor, and number of tractors) at the provincial-level before and after the implementation of ARIP.

The remaining paper is organized as follows: the next section offers some background of ARIP, followed by the discussion of analytical method in this study. Data set used in this study will then be discussed and the empirical results will be presented. The conclusions of this study will be offered in the final section.

2. Agricultural Reform Implementation Project (ARIP)

Turkish government embarked a promising program of agricultural policy program in 2001. This program targeted the phasing out the product and input subsidies and replacing them by direct income support (DIS). Besides, state economic enterprises (SEEs) were to restructured and privatized and Agricultural Sales Co-operative Union (ASCUs) would become financially autonomous member-controlled cooperatives. The objective of the ARIP intends to support the implementation of a new agricultural support system that "will increase productivity in the agriculture sector" (World Bank, 2005, p.3). The main philosophy of the ARIP is to liberalize the Turkish agricultural markets and also the market organization.

Four major components are consisted in the ARIP project: i) decreasing and abolishing input subsidies, ii) privatizing SEEs and reorganizing the agricultural co-operatives, iii) transferring farmers towards to the more profitable crops/products, and iv) utilizing Direct Income Support (DIS) to compensate farmers. Among those four components, reducing input subsidies is mostly related to agricultural input use. Prior to 2001, agricultural inputs (especially fertilizer) had been subsidized to meet the increasing food needs in Turkey. However, the input subsidies were abolished when ARIP was introduced. As a result, the utilization of fertilizer in agriculture clearly declined after ARIP.

To partially compensate the removal of output support and input subsidies, Turkish government initiated the DIS in 2001 under the ARIP Project. The objective of the DIS is to balance the negative impact of reducing or eliminating the supports/protections in agricultural sector on the income of small and medium sized enterprises in a less market-distorting means (Olhan, 2006, p.42). The share of DIS in total agricultural supports has dramatically increased from 7.6% in 2001 to 70.5 % in 2004, which compensated almost half of the income loss of farmers caused by the cuts in agricultural subsidies, and consequently benefited the consumers with a stable agricultural commodity price (Lundell et al, 2004).

In addition, the principals of the ARIP were broadly consistent with the long–term policy direction of the Common Agricultural Policy (CAP) of the EU. Since gaining the EU membership is one of Turkey's current top priorities, continuous policy reform in agricultural sector will help Turkey to demonstrate its commitment to adopt the EU's structure of agricultural policy.

As ARIP project has introduced a wide range of policy reforms in agricultural market, the impact of ARIP has been widely studied in academic literature and policy regime (e.g Arabaci, 2006; Akder, 2007; Olhan, 2006). However, most studies have examined the impacts of ARIP in an aggregate country level. Turkey's agriculture activities are very diversified, ranging from capital-intensive cultivation of high value crops in Western and Southern Turkey to heavily subsidized and protected cereal and livestock production in Northern and Northeastern region (Aerni, 2007). Hence, the impact of ARIP project on agricultural production is expected to be significantly varied across the country. With a recent developed spatial econometrics model, this study will contribute to the literature by distinguishing the influence of policy reform on the agricultural production over provinces

3. Analytical Method

3.1 Model Specification

A Cobb-Douglas production function is hypothesized to represent Turkey's gross revenue of agricultural products (GRAP);

(1) $$y_i = \gamma \prod_{k=1}^{M} x_{ik}^{\beta_k}$$

where, for county i, y_i is GRAP; x_{ik} are factors of production (k = 1,…, 4) including agricultural labor, land, tractor, and fertilizer; γ is total factor productivity; β_k are shares corresponding with input k. Equation (1) is modified to reflect potential spatial variation of the relationships between inputs and outputs of agricultural productions between administrative units;

(2) $$y_i = \gamma \prod_{k=1}^{M} x_{ik}^{\beta_k(u_i, v_i)}$$

where (u_i, v_i) denotes the location coordinates for the centroid of county i and $\beta_k(u_i, v_i)$ are localized parameters for county i corresponding with input k.

When production is stochastic, equation (2) is:

(3) $$y_i = \gamma \prod_{k=1}^{M} x_{ik}^{\beta_k(u_i, v_i)} \varepsilon_i$$

where ε_i is a "random shock". Deviations from the iid assumption with respect to the disturbances suggest the following autoregressive error process;

(4) $$\varepsilon_i = u_i \prod_{\substack{j=1 \\ i \neq j}}^{n} \varepsilon_j^{\lambda_{Error} w_{ij}} ,$$

with u_i lognormally distributed as ~ iid($\mathbf{0}$, $\mathbf{\Omega}$), with E[$\mathbf{uu}'$] = $\mathbf{\Omega}$ and w_{ij} is an element of an exogenous n by n matrix (n the number of locations) identifying county neighborhoods. The error structure is expected when input levels of neighboring counties are correlated. Levels of fertilizer applied may be similar between neighboring counties because they are located in relatively fertile regions. Or labor may be highly concentrated in a given county (e.g., provincial capitals), which is in turn surrounded by a halo of counties with relatively low population densities. Not accounting for the potential geographic interdependencies of these factors may result in omitted variable bias (Anselin and Florax 1995; Anselin 2003).

3.2 Model Estimation

A Cobb-Douglas production function is estimated in three different ways for three different underlying assumptions that are laid out in the model specification section. The first model entails estimating the conventional OLS model, referred as *OLS model* in this study (equation (1)). Second, the model is estimated in geographically weighted regression (GWR) following the local modeling approach suggested by Fotheringham and Brunson (1999) (equation (2)). The estimator is

$$\hat{\boldsymbol{\beta}}_k(\mathbf{u}_i, \mathbf{v}_i) = (\mathbf{X}'\mathbf{A}(\mathbf{u}_i, \mathbf{v}_i)\mathbf{X})^{-1}\mathbf{X}'\mathbf{A}(\mathbf{u}_i, \mathbf{v}_i)\mathbf{Y} \tag{5}$$

where $\hat{\boldsymbol{\beta}}_k$ represents an estimate of $\boldsymbol{\beta}_k$ that is an $n \times m$ matrix with elements of $\hat{\boldsymbol{\beta}}_k(\mathbf{u}_i, \mathbf{v}_i)$; X is an $n \times m$ matrix containing a vector of the x_{ik}; $\mathbf{Y}$ is a vector of y_i; $\mathbf{A}(\mathbf{u}_i, \mathbf{v}_i)$ is an $n \times n$ diagonal matrix in which the diagonal elements are geographical weights for each of the n observations for regression point i. We refer this model as the *GWR model* in this paper.

Third, a GWR regression corrected for spatial error autocorrelation (GWR-SEM) is estimated as a way to address spatial heterogeneity and spatial dependence between disturbances, the *GWR-SEM model* in our case (equation (3)). The GWR regression is re-estimated with the spatially filtered variables $\tilde{\mathbf{X}}$ and $\tilde{\mathbf{Y}}$. We transform the dependent and explanatory variables to filter spatial error autocorrelation using λ.:

$$\hat{\boldsymbol{\beta}}_k(\mathbf{u}_i, \mathbf{v}_i) = (\tilde{\mathbf{X}}'\tilde{\mathbf{A}}(\mathbf{u}_i, \mathbf{v}_i)\tilde{\mathbf{X}})^{-1}\tilde{\mathbf{X}}'\tilde{\mathbf{A}}(\mathbf{u}_i, \mathbf{v}_i)\tilde{\mathbf{Y}} \tag{6}$$

with $\tilde{\mathbf{X}} = (\mathbf{I} - \lambda\mathbf{A})\mathbf{X}$ and $\tilde{\mathbf{Y}} = (\mathbf{I} - \lambda\mathbf{A})\mathbf{Y}$. We re-calibrate weight matrix using the filtered variables, so that the diagonal elements $\tilde{a}_{ij}$ of the weight matrix, $\tilde{\mathbf{A}}$ is re-estimated. The n by n matrix $\tilde{\mathbf{A}}$ addresses spatial heterogeneity, with diagonal elements identifying the location of other counties relative to county i and zeros in off-diagonal positions (Fotheringham et al., 2002). The mechanism [$(\mathbf{I} - \lambda\mathbf{A})$] filters out spatial error autocorrelation associated with the explanatory and dependent variables while estimating local coefficients.

Different kernel functions $K(d_{ij}/b)$ determine the diagonal elements of the weight matrix $\mathbf{A}$ and $\tilde{\mathbf{A}}$, with d_{ij} the distance between point *i* and *j*, *b* a value that minimizes the residual sum of squares of predicted values (e.g., a cross-validation (CV) procedure). An adaptive bi-weight function is used to geographically weight observations. The bi-weight function is:

(6) $$a_{ij} = \left[1-\left(d_{ij}/d_{\max}(q)\right)^2\right]^2 \text{ if } d_{ij} \le d_{\max}(q), \text{ otherwise } a_{ij} = 0,$$

where *j* represents a data point in space and *i* represents any point in space where local parameters are estimated, d_{ij} the Euclidean distance between points *i* and *j*, and $d_{\max}$ the maximum distance between observation *i* and its *q* nearest neighbors (Fotheringham, Brunsdon, and Charlton, 2002). The weight attributed to regression point *i* is one. Weights attributed to *j* observations in the neighborhood of *i* are less than one and are zero when the distance between *i* and *j* is greater than $d_{\max}$. Therefore, as d_{ij} increases, the influence of observation *j* on local regression point *i* decreases up to a definitive threshold. A cross-validation approach selects the optimal number of neighbors (Cleveland and Devlin, 1988).

3.3 Model Selection

The residuals of OLS, GWR, and GWR-SEM are tested for spatial error autocorrelation using a Lagrange Multiplier (LM) test (Anselin, 1988). The statistic is distributed as a χ^2 variate with 1 degree of freedom. The null hypothesis is $\lambda = 0$. If the null hypothesis of spatial error independence is not rejected, Akaike Information Criterion and residual sum of square are compared to measure goodness of fit for each model as next model selection criteria.

4. Data

Based on the climate, location, human habitat, agricultural diversities, topography and other factors, Turkey can be divided into seven regions with total 81 provinces. Figure 1 presents the boundaries of provinces and regions in Turkey. Province-level data of the output variable, gross revenue of agricultural production (GRAP), in this study are obtained from TurkStat. The GRAP includes the revenue of animal products, livestock, field crops, fruits and vegetables in million Turkish Liras. The data of input variables, including agricultural land, agricultural labor, number of tractor, and chemical fertilizer use, are also collected from TurkStat. The official data of agricultural labor is not available so the rural population is used as a proxy of agricultural labor since agricultural labor is primarily composed by rural population in each province. The number of tractor is used as a proxy for machinery utilization. The GRAP and input variables, except agricultural population, are available from 1998 through 2007. However, the rural/agricultural population data is only available in 2000 and 2007 from the agricultural census. Therefore, we use those two years to conduct our analysis and compare the changes of output elasticities with respect to various inputs before and after the implementation of APRI.

Table 1 summarizes the simple statistics of the output and input variables. In 2000, the average province had 325,667 ha of land used for agricultural products, employed nearly 294,000 agricultural labors, utilized 11,628 tractors and 128,702 tons of chemical fertilizers to produce about 330,000 billion Turkish Liras worth of agricultural products. The average province GRAP tripled in 2007, which is likely to be affected by the international price surges in the second half of 2007. The average agricultural inputs resources, except the tractor, decreased between 2000 and 2007. Average province agricultural labor employment dropped by about 12% while fertilizer use also reduced by nearly 7%. The average number of tractors per province increased 12% over the seven years. The decrease of utilizing some inputs, such as fertilizer, is likely to result from the reduction/elimination of input subsidies.

5. Empirical results

Table 2 presents parameter estimates of the OLS model in 2000 and 2007. In both years, all four input elasticities of GRAP are positive, indicating that use additional one-percent of those inputs will increase the total agricultural output. All agricultural inputs are statistically significant at the level of 95 percent, except agricultural land in 2000 and fertilizer in 2007. Agricultural labor is the most crucial input among those four factors to GRAP. Before implementation of the APRI project, fertilizer is a statistically significant input and with a high impact on GRAP with an elasticity of 0.12. After removing the subsidies, the influence of fertilizer clearly dropped and become statistically insignificant. In contrast, land use for agriculture becomes statistically significant in the post-APRI era with a significant elasticity of 0.21.

As described in the method section, the estimation of parameters can be biased if the serial autocorrelation in the model is not corrected. Table 3 summarized the test and performance statistics between three models, OLS, GWR, and GWR-SEM, for both 2000 and 2007. The spatial LM statistics show the existence of spatial autocorrelation in the OLS model in both 2000 and 2007, while GWR and GWR-SEM have corrected the spatial dependence issue. Comparing OLS, GWR and GWR-SEM models, a higher adjusted R^2 associated with GWR and GWR-SEM reflects a better fitness of the models with correction of spatial autocorrelation. The significant reduction of residual sum of squared errors in the GWR and GWR-SEM models is also observed. The AIC statistics also show that the performance of the GWR and GWR-SEM models outperforms the OLS model. Hence, the implicit assumption of no spatial variation in parameters under the OLS model is a misrepresentation of agricultural production in Turkey. Because the spatial variation in parameters has been corrected in both GWR and GWR-SEM models, we choose GWR-SEM model in this analysis based on its lower AIC statistics.

The summary of parameter estimate of GWR-SEM is presented in Table 4. The estimated GWR-SEM model suggests labor has the most consistent influence on agriculture production revenue across provinces, while use of tractor has the highest contribution to agricultural production overall. The GWR-SEM model produces input elasticities that account for the spatial heterogeneity, and vary across province. Intuitively, provinces that are adjacent or close in distance are more likely to present similar parameters. Estimated output elasticities for provinces are expected to be varied when the distances between them are significant.

A summary of the varying output elasticites with respect to four inputs and scale for the seven regions in Turkey generated by the GWR-SEM model is summarized in Table 5. It is clear that tractor is the major input for agricultural production revenue in the Western region (e.g. Marmara and Aegean), while additional land use for agriculture brings more agricultural value in the Eastern region (Eastern Anatolia and Southeast Anatolia). Labor is the crucial factor to agricultural production revenue across the whole country, while the elastcities is much higher in the Eastern region than the Western zone. This pattern is consistent between 2000 and 2007; however, the marginal contribution of inputs has improved over the period. For example, the output elasticity of fertilizer use has improved in the Western and Central regions. This can be explained that fertilizer is likely to be overused when significant input subsidy is offered to farmers in 2000. In 2007, the marginal contribution of land to agricultural production in the Eastern region also improves, which possibility results from the local development project has improved the soil quality through irrigation.

In order to illustrate the spatial heterogeneity between the parameters of agricultural inputs across the country, the estimates of the GWR-SEM for labor, land, tractor, fertilizer and scale elasticities for individual province are mapped in Figures 2 through 6, respectively. The figures clearly show that spatial variation in the parameters of the model is considerable. Output elasticity of labor input in Figure 2 is less than unitary in all regions which was between 0.8-1.0 in part of Black sea, all eastern Anatolia and major part of southern Anatolia. But, size of input-output elasticity of labor in all of the eastern and southeastern Anatolia declined from 0.8-0.1 in 2000 to 0.4-0.6 in 2007.

This remarkable change in labor input elasticity is probably attributed tremendous declining of employment in agricultural during 2000-2007 (7769 thousand person in 2000 and 4867 in 2007). However, with the ARIP sugar quota regime started to implement in 2002/2003 marketing season, tobacco policy changes[1], privatization of alcohol plant of Turkish RAKI production monopoly, and privatization of cigarettes plants of TEKEL (market share was 61% in cigarettes market) leaded tremendous declining of producers of sugar beet and tobacco in the southeast-east Anatolia regions and increasing unemployment due to closing down of privatized alcohol and cigarettes plant in the regions. The number of tobacco producer was around 406, 252 and 180 thousand in 2002, 2005 and 2009 respectively. Tobacco production was around 160, 135 and 93 thousand tons in 2002, 2005 and 2009 respectively. Similarly sugar beet production was 18.8 million tons in 2000 and declined to 12.4 million thousand in 2007.

Output elasticities with respect to land is presented in Figure 3. Before ARIP project, output elasticity of land input was very inelastic (less than 0.2) in all regions and even negative in many regions which are part Aegean (Aydın, Manisa and Izmir provinces), Mediterranean

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[1] Firstly, until 2003, tobacco production restricted under quota regime and almost prohibited in south-eastern Anatolia and black sea regions, alternative production support implemented for tobacco producers and finally allowed to tobacco production under production contract with private companies in 2003 and thereafter

(except Mugla province), central south and central east (Kahraman Maras, Nigde, Kayseri and Malatya province), all east and south Anatolia and east part of black sea. All of the regions which had negative elasticity can be characterized by land scarcity and dominant production pattern with field crops. Post policy period (in 2007), elasticity of land input in all west and Mediterranean region became negative and many part of east and south eastern Anatolia regions increased a range from 0.0-0.2 to 0.2-0.4. Elasticity of land input did not significantly change from 2000 to 2007 in the remaining regions.

The considerable change in size of elasticity in east and south eastern Anatolia regions can be stemming from post reform policies such as per hectare subsidies for fodder crops, milk and meat premium payment and other input subsidies for livestock and crops sector (such as dry beans) plus direct income payment to farmers. Furthermore, premium payment for cotton and oilseed was important for producers in which south Anatolia region is major producer of cotton and lentils. These policies most probably increased output quantity of crops and animal sector in the mentioned regions. Expansion of irrigated area in south Anatolia region and productivity growth can be regarded another factors contributed to changes in size of land input elasticity.

Output elasticity of tractor input was positive in all regions in 2000 and exhibited a trend which increases from east to west (see Figure 4). However, it was much higher in Marmara regions (including trace part of the country) then all other regions. Between 2000 and 2007, the elasticity of tractor input declined in Marmara and much part of east and eastern Anatolia regions. These changes can be attributed to production pattern changes during post ARIP periods due to direct income payment and subsidies for output and inputs. Also declining of real interest rate and overvalued exchange rate allowed producers to buy a tractor much more chapter than pre ARIP implementation periods.

In Figure 5, output elasticity of fertilizer input was less than 0.4 in 2000 and even negative in all part of Marmara, major part of Eagean regions, part of east Mediterranean and central east Anatolia and major part of southeastern Anatolia. But in 2007, elasticity of fertilizer input was only negative part of Southeastern and eastern Anatolia and size of elasticity was between 0.0-0.2 all but central black sea regions. Notable change observed between year 2000 and 2007 is that negative elasticity disappeared in 2007 except part of Southeastern and eastern Anatolia. These phenomena can be attributed to fertilizer subsidy removal after 2001, but again partial fertilizer subsidy restarted in 2005 and thereafter which can not be comparable with pre ARIP period in terms of percentage term. We can conclude that increasing fertilizer cost has positively increased efficiency in fertilizer use.

Figure 6 shows province-specific scale elasticity in Turkish agricultural production. The scale elasticity is generated from summing the labor, land, tractor and fertilizer elasticities. The figure suggests that the increasing return to scale was primarily observed in the Marmara and Aegean regions because of the high elasticity of tractor use. The constant returns to scale was generally observed in partial Mediterranean, Black Sea and Central Anatolia regions. The decreasing return to scale provinces had mostly improved between 2000 and 2007. Only a few provinces in the Black Sea region remained the less productivity status in 2007.

6. Conclusions

Turkey's agricultural market has experienced significant changes over the past decade because of the introduction of the Agricultural Reform Implementation Project in 2001. The ARIP project reduces/eliminates strong input subsidies, adopts direct income support, and prompts agricultural sector to be a more market-oriented sector. The execution of ARIP tends to bring the country more in line with the EU agricultural policies and to mitigate the regional economic inequalities between the west and east regions. Using a province-level data, this study evaluates the impact of ARIP project on agricultural production in Turkey. An agricultural production function incorporating with a spatially heterogeneous error component is formed. The GWR-SEM model analyzes spatial variation of output-input elasticities and identifies the clusters of high output-input elasticities before and after the introduction of ARIP. The output elasticities with respect to input generally improved across the country after the implementation of ARIP. Among all four factors, labor is the key input to agricultural production revenue in the nation. Tractor has the most influence on the agricultural revenue on the Western region, while agricultural land has more contribution to the Eastern and Southeastern zones.

The recognition of the suitable inputs for agricultural production in each province/region has an important implication. As regional economic inequalities are significant in Turkey and have been increasing, utilization of the efficient agricultural policies will have crucial influence on the regional economic inequalities in Turkey. Based on the findings generated from this study, allocating the resources to prompt the most productivity agricultural factors in each region and improving the quality of other less efficient inputs will help to improve the regional development and mitigate the economic inequalities among regions.

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Table 1. Descriptive statistics of province-level agricultural output and inputs

Variable	Unit	Mean	Std. dev.	Min.	Max.
Year 2000					
GVAO	10^6 TL	329,930,304	264,331,340	44,624,082	1,262,518,552
Ag. Land	Ha	325,667	346,966.68	6,587	2,587,504
Ag. Labor	Person	293,798	202,343.38	39,108	933,136
N. of tractor	Car	11,628	10,478.19	2	44,377
Chemical fertilizer	Tons	128,702	140,859.86	27	791,620
Year 2007					
GVAO	10^6 TL	1,288,750,448	1099028470	160114675	5079035791
Ag. Land	Ha	307253	302389.10	11448	2140817
Ag. Labor	Person	257264	213453.32	29653	1399579
N. of tractor	Car	13039	11854.75	7	60674
Chemical fertilizer	Tons	119875	136837.53	36	730068

Table 2. Parameter estimates of the OLS model of Turkish agricultural production

	Year 2000			***Year 2007***	
Variable	Estimates	Standard error		Estimates	Standard error
Intercept	6.58	0.57		7.14	0.56
Ln(Labor)	0.57	0.07		0.52	0.07
Ln(Land)	0.09	0.10		0.21	0.09
Ln(Tractor)	0.11	0.04		0.09	0.04
Ln(Fertilizer)	0.12	0.06		0.06	0.05

Table 3. Comparison of Performance among OLS, GWR, and GWR-SEM

	OLS	GWR	GWR-SEM
Year 2000			
Bandwidth		35	37
R^2	0.83	0.91	0.90
Lambda	0.26		
Residual Sum of Square	9.19	3.51	3.58
AIC	63.62	39.81	36.86
Spatial LM Statistic	6.04**	0.002	0.503
Year 2007			
Bandwidth		39	51
R^2	0.78	0.90	0.90
Lambda	0.31		
Residual Sum of Square	11.83	5.35	5.85
AIC	84.05	65.28	55.62
Spatial LM Statistic	11.385***	1.98	0.17

* 1% significance

Table 4. Parameter estimate summary of the local model of Turkish agricultural production

Variable	Minimum	Lower quartile	Medium	Upper quartile	Maximum
Year 2000					
Intercept	5.70	6.18	6.50	6.85	7.54
Ln(Labor)	0.16	0.26	0.48	0.67	0.80
Ln(Land)	-0.19	-0.07	0.00	0.10	0.19
Ln(Tractor)	0.01	0.02	0.26	0.83	1.11
Ln(Fertilizer)	-0.17	-0.02	0.03	0.11	0.34
Year 2007					
Intercept	6.66	7.09	7.20	7.30	7.72
Ln(Labor)	0.26	0.30	0.52	0.56	0.60
Ln(Land)	-0.13	-0.11	0.07	0.19	0.30
Ln(Tractor)	-0.02	0.00	0.12	0.79	0.86
Ln(Fertilizer)	-0.01	0.02	0.05	0.10	0.30

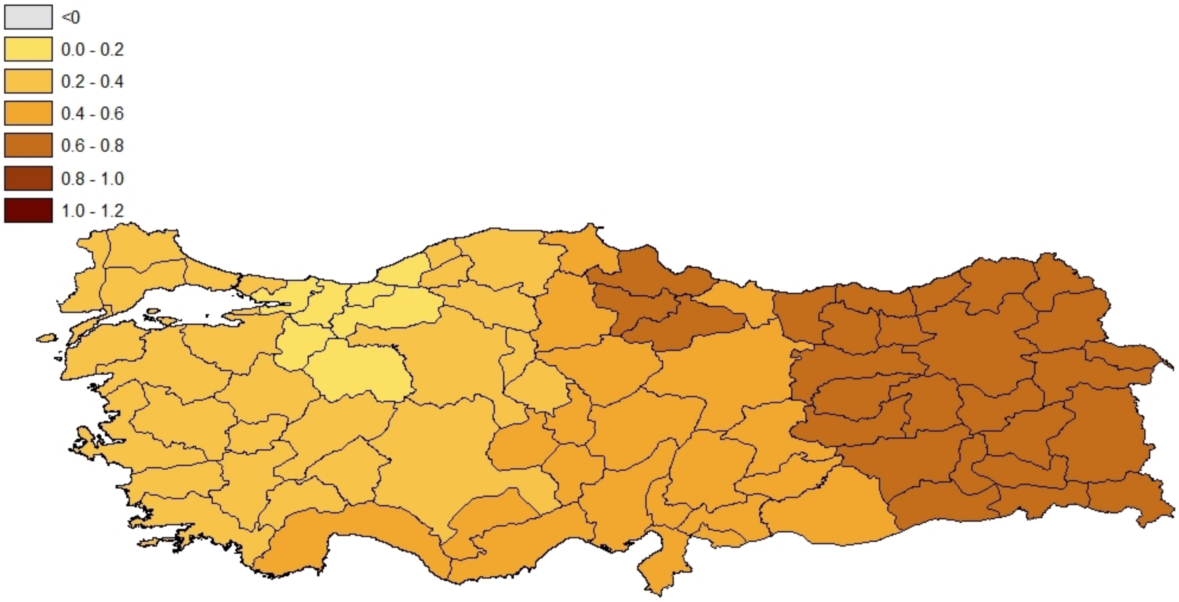
Table 5. Mean elasticity estimates of local regression by region[a]

Region	Ln(Fertilizer)	Ln(Tractor)	Ln(Labor)	Ln(Land)	Scale elasticity
Year 2000					
Marmara	-0.12 (0.05)	1.06 (0.03)	0.22 (0.04)	-0.06 (0.04)	1.10 (0.01)
Aegean	-0.03 (0.07)	0.83 (0.11)	0.28 (0.05)	-0.03 (0.03)	1.05 (0.03)
Mediterranean	0.05 (0.10)	0.34 (0.20)	0.46 (0.11)	0.05 (0.08)	0.89 (0.08)
Black Sea	0.15 (0.10)	0.36 (0.38)	0.49 (0.22)	-0.07 (0.11)	0.93 (0.08)
Central Anatolia	0.08 (0.10)	0.50 (0.29)	0.41 (0.14)	-0.02 (0.09)	0.97 (0.09)
Eastern Anatolia	0.02 (0.04)	0.02 (0.01)	0.73 (0.09)	0.12 (0.03)	0.89 (0.04)
Southeast Anatolia	0.04 (0.06)	0.04 (0.04)	0.64 (0.14)	0.13 (0.03)	0.86 (0.06)
Year 2007					
Marmara	0.04 (0.02)	0.84 (0.02)	0.28 (0.01)	-0.13 (0.00)	1.03 (0.01)
Aegean	0.03 (0.01)	0.82 (0.01)	0.30 (0.01)	-0.11 (0.01)	1.05 (0.00)
Mediterranean	0.06 (0.02)	0.37 (0.34)	0.46 (0.12)	0.06 (0.12)	0.95 (0.09)
Black Sea	0.14 (0.09)	0.23 (0.29)	0.48 (0.14)	0.03 (0.12)	0.88 (0.08)
Central Anatolia	0.14 (0.06)	0.31 (0.23)	0.47 (0.10)	0.04 (0.08)	0.96 (0.06)
Eastern Anatolia	0.01 (0.03)	-0.01 (0.01)	0.57 (0.01)	0.24 (0.04)	0.81 (0.01)
Southeast Anatolia	0.03 (0.04)	0.01 (0.03)	0.55 (0.01)	0.24 (0.05)	0.83 (0.01)

[a] Number in parentheses are standard deviations.

Figure 1. Regions of Turkey

Year 2000



Year 2007

Figure 2. Output elasticities with respect to labor for province-level agricultural production in Turkey

Year 2000

Year 2007

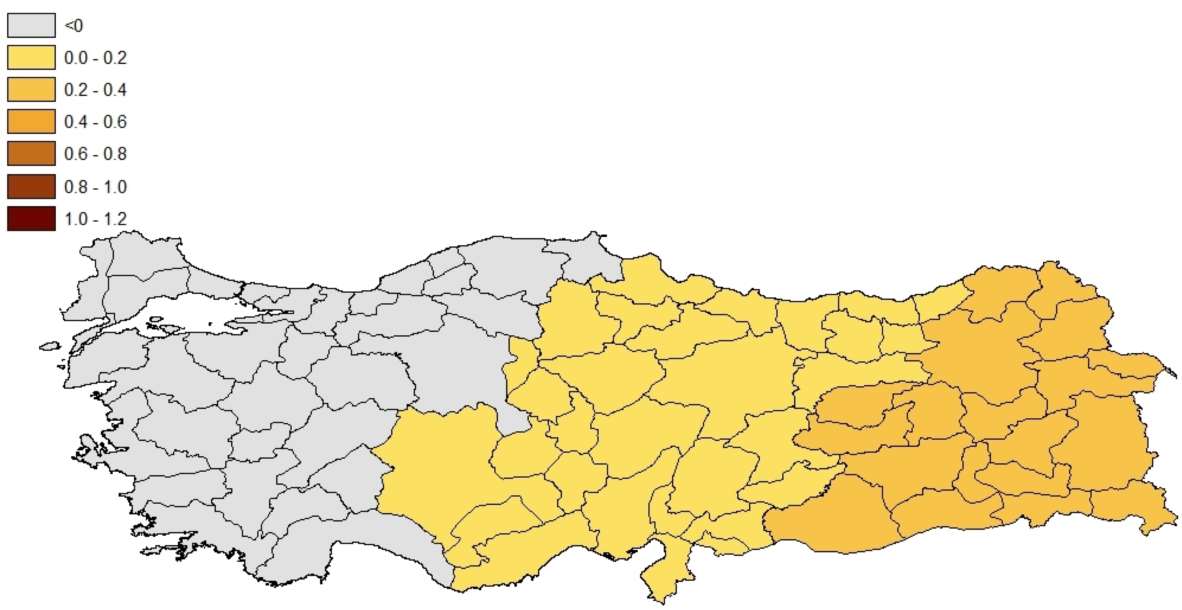
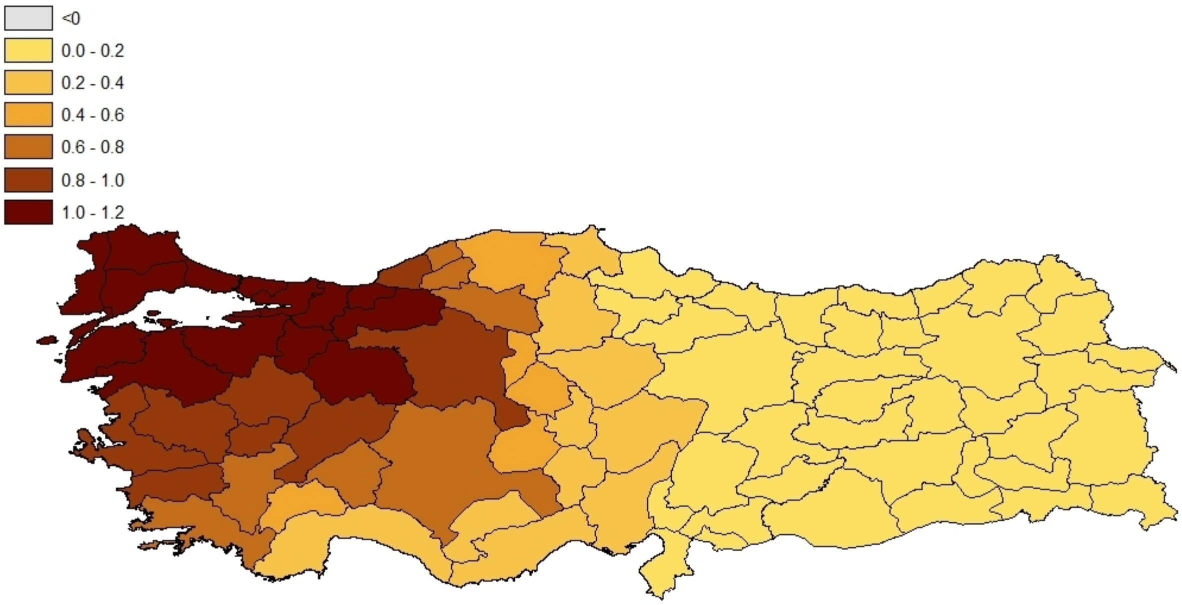


Figure 3. Output elasticities with respect to land for province-level agricultural production in Turkey

Year 2000



Year 2007

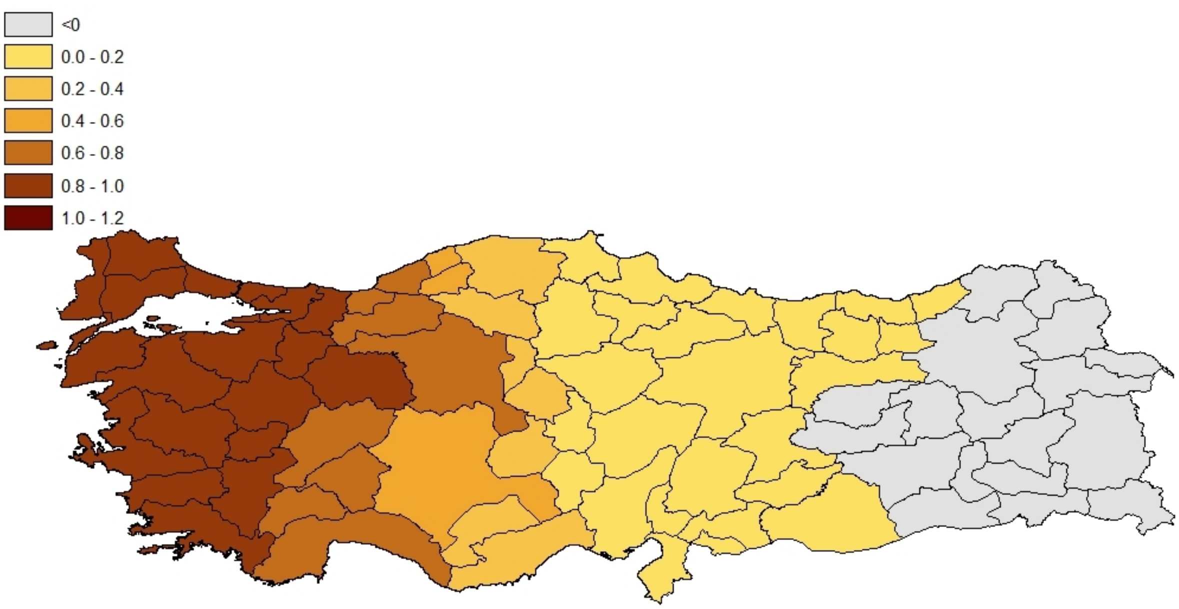
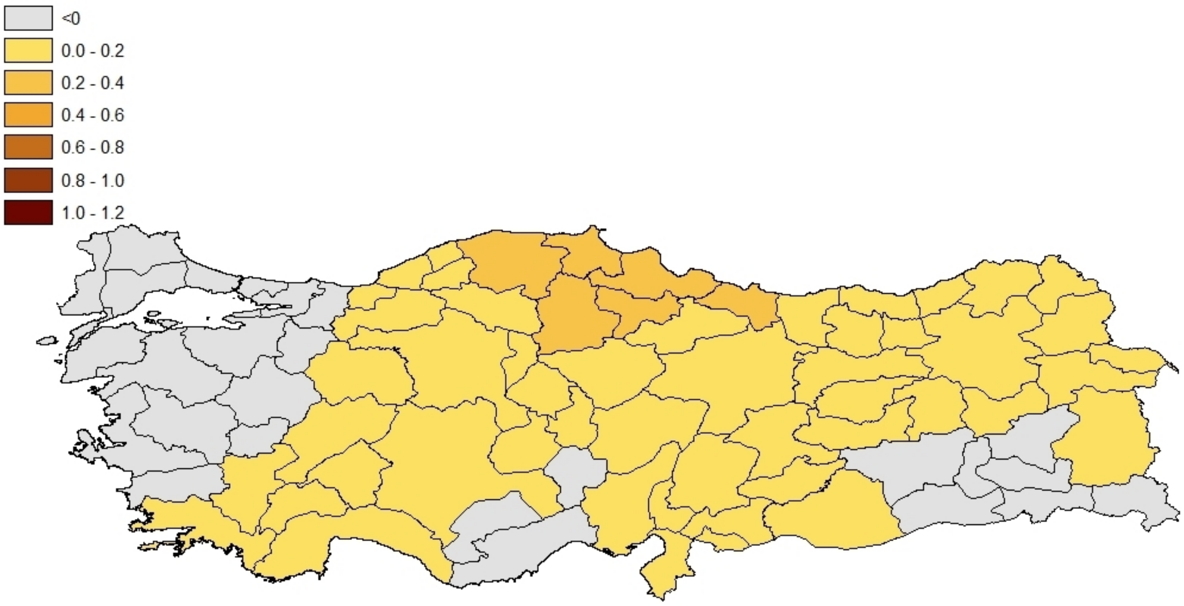


Figure 4. Output elasticities with respect to tractor for province-level agricultural production in Turkey

Year 2000



Year 2007

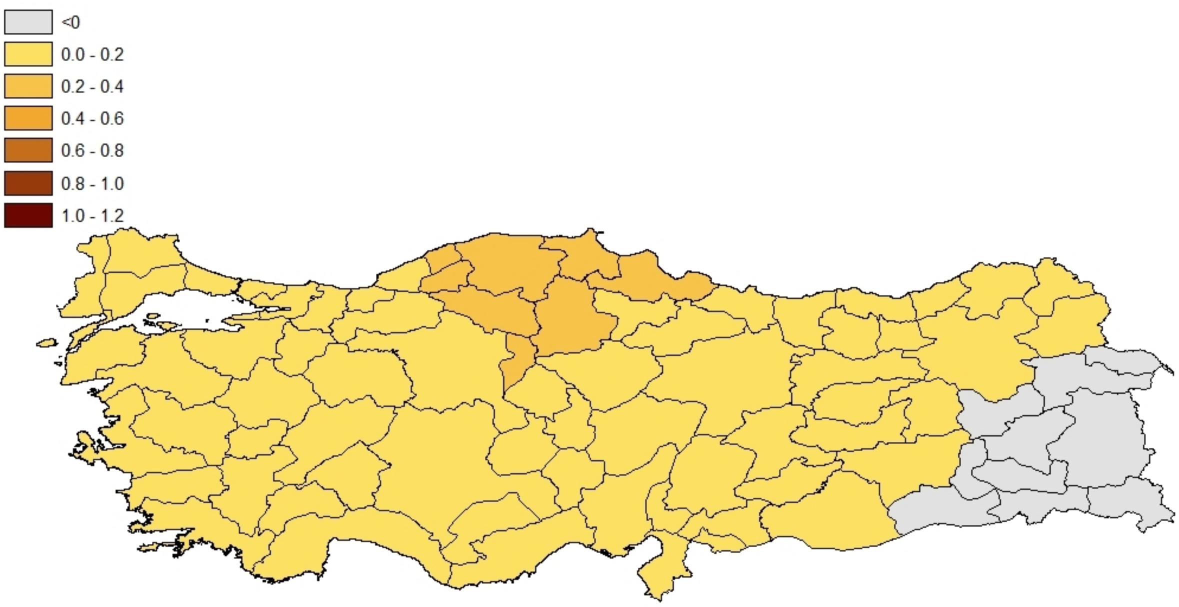
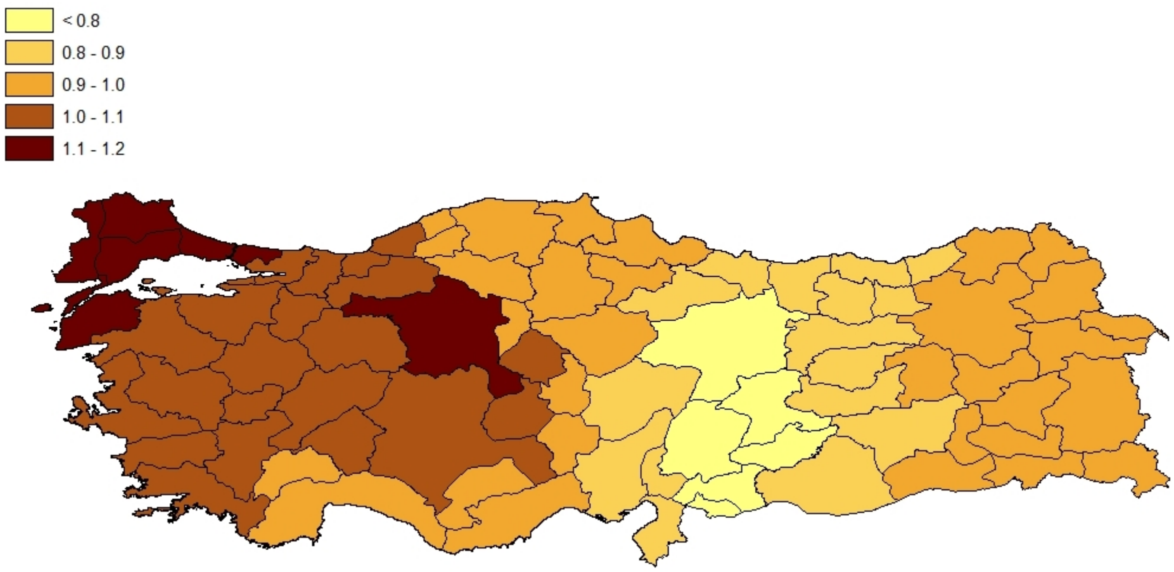


Figure 5. Output elasticities with respect to fertilizer for province-level agricultural production in Turkey

Year 2000



Year 2007

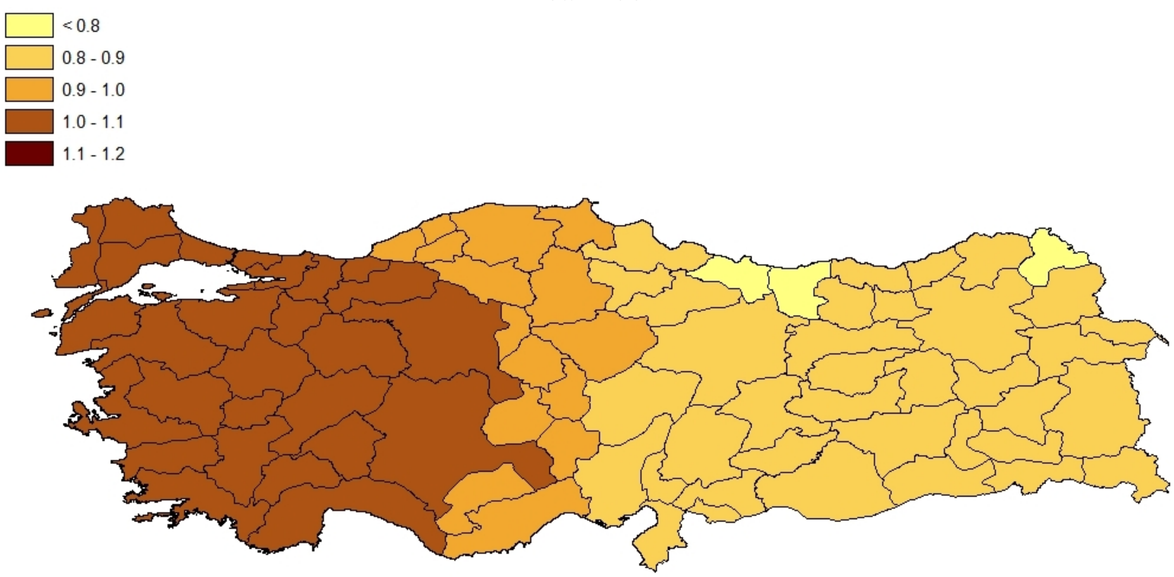


Figure 6. Scale elasticities of province-level agricultural production in Turkey