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Barley Productivity Decomposition in Iran: Comparison of TT, GI, MGI, and GTTI Approaches

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Abstract

In this paper, the authors present new indices for estimating technical change, return to scale, and *TFP* growth, as well as its decomposition. These indices, Modified General Index (*MGI*), Generalized Modified General Index (*GMGI*), and General Time Trend index (*GTTI*), are generalization of General Index approaches. These approaches were used for productivity decomposition of Iran's barely production across the period 2000-2012 in 20 provinces. To select the best approaches, estimated TFP growth of *TT, GI, MGI* and *GTTI* are compared with *Divisia Index*. Results show that differences between barley TFP growth of *TT, GI, MGI*, and *GTTI* approaches with Divisia Index are 39.12, 17.94, 9.71, and 1.61 percent, respectively. The findings revealed that MGI method is appropriate when time series data or panel data with limited cross-section data are used. In addition, when only need to compare periods of time that are not regular (for evaluation plan or policies), it is suggested *GMGI* method. When time series data or panel data with limited cross section data are used, and there is a trend in every period, the *GTTI* method is recommended for estimating technical change, return to scale, and *TFP* growth.

Keywords:
Barley, productivity; Modified General Index; Generalized Modified General Index; General Time Trend index

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INTRODUCTION

Productivity measurement provides a key indicator for the performance of an economic activity, and helps policy makers to design optimal policies to enhance productivity (Kavoosi et al., 2010). Its importance has motivated economist to present and test approaches to determine technical change, return to scale, and TFP growth. So, in this sense, some indices have been engendered in literature (e.g. Baltagi & Griffin, 1988; Baltagi et al., 1995; Capalbo, 1988; Diewert, 1976; Kumbhakar et al., 2000; Shahbazi & Abbasifar, 2014). Approaches to measure technical change have been categorized into four groups including econometric estimation, Divisia indices, exact index numbers and nonparametric method using linear programs (Baltagi & Griffin, 1988). Econometric approaches which use cost, production and newly profit function (e.g. Kumbhakar, 2002) can estimate technical change, return to scale, and TFP growth. In literature, technical change, return to scale, and TFP growth by cost function are estimated considered by two approaches of Time Trend and General Index. General Index was proposed by Baltagi and Griffin (1988). Their procedure gives a measure of TFP growth that is generally found to be close to Divisia index introduced by Kumbhakar (2002) and Salami and Shahbazi (2010). Then, similar to entering Time Trend index in cost function, Kumbhakar (2004) considered to the General index. That is, General Index is entered in cost function similar to Time Trend.

In this paper, first of all, two approaches of Kumbhakar (2004)'s Time Trend and General Index were reviewed. Then, given the incompactness of Kumbhakar (2004)'s General Index, three indices including Modified General Index, Generalized Modified General Index and General Time Trend Index were proposed. These approaches are used to decompose the productivity of Iran's barely production for the period 2000-2012 in 20 provinces. To select the best approaches, the estimated *TFP* growth of *TT, GI, MGI* and *GTTI* are compared with Divisia Index.

MATERIAL AND METHOD

Dual Translog cost function production process (e.g. Kumbhakar, 2004 ; Kumbhakar & Heshmati, 1996), are applied because it imposes minimum a priori restrictions on the underlying production technology, and it approximates a wide variety of functional forms (Kumbhakar, 2004). According to mentioned models, 5 approaches will be compared together.

The Time Trend (TT) Model (Proposed By Binswanger, 1974)

Assuming that panel data are available, the single output Translog cost function can be written as:

$$Ln\ C_{it}=\beta_0+\Sigma_j\ \beta_j\ Ln\ P_{jit}+\beta_y\ Ln\ Y_{it}+\beta_t\ t+0.5\ [\Sigma_j\Sigma_j\beta_{jk}\ Ln\ P_{jit}\ Ln\ P_{kit}+\beta_{yy}(Ln\ Y_{it})2+\beta_{tt}(t)^2]+\Sigma_j\beta_{jy}\ Ln\ P_{jit}\ Ln\ Y_{it}+\Sigma_j\beta_{jt}\ Ln\ P_{jit}t+\beta_{yt}\ Ln\ Y_{it}\ t \quad (1)$$

where C is total cost, P_j is the j_{th} input prices, and Y is output. The subscript i and t denote province and time, respectively. Regularity condition can be imposed by $\beta_{jk}=\beta_{kj}$, $\Sigma_j\beta_j=1$, $\Sigma_j\beta_{jk}=0\forall k$, $\Sigma_j\beta_{jy}=0$, and $\Sigma_j\beta_{jt}=0$. The time variable t in the cost function represents shifts in the production technology. From the above cost function, one can compute technical change *(TC/ TT)* as follows:

$$TC/TT_{it}=\partial\ Ln\ C_{it}/\partial\ t=-[\beta_t+\beta_{tt}+\Sigma_j\beta_{jt}\ Ln\ P_{jit}+\beta_{yt}\ Ln\ Y_{it}] \quad (2)$$

One can measure returns to scale from:

$$RTS/TT_{it}=1/(\partial LnC_{it}/\partial LnY_{it})=1/(\beta_y+\beta_{yy}\ Ln\ Y_{it}+\Sigma_j\beta_{jy}\ Ln\ P_{jit}+\beta_{yt}t) \quad (3)$$

Finally, using the definition of TFP growth (the Divisia index) it can be shown that:

$$TFP=Y-\Sigma_jS_jx_j=TC/TT+Y(1-(1/RTS/TT)) \quad (4)$$

where, S_j is the cost share of the j_{th} input. TFP growth is, thus, decomposed into a technical change (TC) and a return to scale (RTS) component. These components are calculated using the estimated parameters of the cost function and data.

The General Index (GI) Model (Proposed by Kumbhakar, 2004)

The *Translog* cost function incorporating the General Index can be written as:

$$\text{Ln } C_{it} = \beta_0 + \sum_j \beta_j \text{Ln } P_{jit} + \beta_y \text{Ln } Y_{it} + \beta_a A(t) + 0.5\left[\sum_j \sum_j \beta_{jk} \text{Ln } P_{jit} \text{Ln } P_{kit} + \beta_{yy} (\text{Ln } Y_{it})^2 + \beta_{aa}(A(t))^2\right] + \sum_j \beta_{jy} \text{Ln } P_{jit} \text{Ln } Y_{it} + \sum_j \beta_{jt} \text{Ln } P_{jit} A(t) + \beta_{yt} \text{Ln } Y_{it} A(t). \quad (5)$$

where, C is total cost, P_j is the jth input prices, and Y is output. The subscript i and t denote province and time, respectively. Regularity condition can be imposed by $\beta_{jk}=\beta_{kj}$, $\sum_j \beta_j=1$, $\sum_j \beta_{jk}=0 \forall k$, $\sum_j \beta_{jy}=0$, and $\sum_j \beta_{jt}=0$. The *General Index* variable $A(t)$ in the cost function represents shifts in the production technology. Baltagi and Griffin (1988) demonstrated that $A(t)=\sum_{i=2}^{t} \lambda_i L_i$ where L_t's are dummy variables for years and λ's must be specified.

Analogous to the time trend model, technical change in the general index model (TC/GI) is defined as:

$$\text{TC/GI}_{it} = -[A(t) - A(t-1)] \left[\beta_a + 0.5\,\beta_{aa}[A(t) - A(t-1)] + \sum_j \beta_{jt} \text{Ln } P_{jit} + \beta_{yt} \text{Ln } Y_{it}\right] \quad (6)$$

Finally, returns to scale are obtained from:

$RTS/GI_{it}=1/(\partial LnC_{it}/\partial LnY_{it})=1/(\beta_y+\beta_{yy} LnY_{it} +\sum_j \beta_{jy} LnP_{jit}+\beta_{yt}A(t))$ (7)

and TFP growth from:

$TFP= Y-\sum_j S_j x_j= TC/GI+ Y(1-(1/RTS/GI))$ (8)

The Modified General Index (MGI) model

To use *General Index*, data are required as panel. That is, *General Index* approach can only be used for panel data. Using *General Index* for time series data can cause a degree of freedom problem. This problem can be solved by *MGI*. That is, *MGI* can be used for both panel and time series data. The *Translog* cost function incorporating the *General Index* can be written as:

$$\text{Ln } C_{it} = \beta_0 + \sum_j \beta_j \text{Ln } P_{jit} + \beta_y \text{Ln } Y_{it} + \beta_a A(th) + 0.5\left[\sum_j \sum_j \beta_{jk} \text{Ln } P_{jit} \text{Ln } P_{kit} + \beta_{yy} (\text{Ln } Y_{it})^2 + \beta_{aa}(A(th))^2\right] + \sum_j \beta_{jy} \text{Ln } P_{jit} \text{Ln } Y_{it} + \sum_j \beta_{jt} \text{Ln } P_{jit} A(th) + \beta_{yt} \text{Ln } Y_{it} A(th). \quad (9)$$

where, C is total cost, Pj is the j_{th} input prices, and Y is output. The subscript i and t denote province and time, respectively. Regularity condition can be imposed by $\beta_{jk}=\beta_{kj}$, $\sum_j \beta_j=1$, $\sum_j \beta_{jk}=0 \forall k$, $\sum_j \beta_{jy}=0$, and $\sum_j \beta_{jt}=0$. $A(th)$ represents the production technology. In this approach, $A(th)$ is defined as $A(th)=\sum_{h=i} \lambda_h L_h$ where L_h's are dummy variables for period of time as interval time. That is, L_h, for example, is a dummy variable for 2, 3, or more years (i is the length of period of time not a year). The choice of this period is one of our problems. If a firm or country has a regular plan or policy for the development of industries or an economic sector (such as the agricultural sector), the period of the fulfillment of the plan or policy can be preferred as h. If not, h can be determined by *LR* test. If h is small, the degree of freedom problem will be tougher. If h =1, *MGI* will be similar to *GI*.

Analogous to the *GI*, technical change in the *MGI* model *(TC/MGI)* is defined as:

$$\text{TC/MGI}_{it} = -[A(th) - A(th-h)] \left[\beta_a + 0.5\,\beta_{aa}[A(th) - A(th-h)] + \sum_j \beta_{jt} \text{Ln } P_{jit} + \beta_{yt} \text{Ln } Y_{it}\right] \quad (10)$$

Finally, returns to scale are obtained from:

$RTS/MGI_{it}=1/(\partial LnC_{it}/\partial LnY_{it})=1/(\beta_y+\beta_{yy}LnY_{it}+\sum_j \beta_{jy}Ln P_{jit}+\beta_{yt}A(th))$ (11)

and *TFP* growth from:

$TFP= Y-\sum_j S_j x_j= TC/GI+ Y(1-(1/RTS/MGI))$ (12)

The Generalized Modified General Index (GMGI) model

To use Modified General Index, it needs to have regular period of time. Regular period of time can be occurred in firms or countries that have regular development plans. Sometimes, some firms or countries are encountered to irregular plan or lack of planning. In such a case, different time periods should be compared with unequal years. For example, researcher wants to compare technical change of drought period within the time period 2003-2005 (3 years), with the drought period within the time period 2006-2011 (5 years). In this case MGI cannot be used for this comparison. GMGI can solve this problem. In this approach, *A(th)* are defined for irregular period. For example, $A(t)=\lambda_2 L_{6\text{-}10}+\lambda_3 L_{11\text{-}12}+\quad+\lambda_t L_{t\text{-}h\text{-}T}$. This means that a dummy variable is chosen for years of 6 to 10, and another dummy variable for years of 11-12. In addition, technical change, return to scale and TFP growth of years 6-10 (5 Years) can be compared with years of 11-12 (2 years). If time periods are equal, *MGI* will be equal to *GMGI*.

The General Time Trend Index (GTTI) model

There is need for technology that has a constant trend in a certain time period to be able to use *MGI* and *GMGI*. Firms or countries usually do not encounter a constant trend in time periods. For example, to compare technical change of drought period during 2003-2005 (3 years) with technical change of drought period during 2006-2011 (5 years), the first and latest years of two periods are not similar. That is, in a period, there is a trend which is different from another period. To consider this problem, we suggest *GTTI*. The *Translog* cost function incorporating the *GTTI* can be written as:

$$\text{Ln } C_{it} = \beta_0 + \sum_j \beta_j \text{Ln } P_{jit} + \beta_y \text{Ln } Y_{it} + \beta_a A(tt) + 0.5\left[\sum_j \sum_j \beta_{jk} \text{Ln } P_{jit} \text{Ln } P_{kit} + \beta_{yy} (\text{Ln } Y_{it})^2 + \beta_{aa}(A(tt))^2\right] + \sum_j \beta_{jy} \text{Ln } P_{jit} \text{Ln } Y_{it} + \sum_j \beta_{jt} \text{Ln } P_{jit} A(tt) + \beta_{yt} \text{Ln } Y_{it} A(tt). \quad (13)$$

where, C is total cost, P_j is the j_{th} input prices, and Y is output. The subscript i and t denote province and time, respectively. Regularity condition can be imposed by $\beta_{jk}=\beta_{kj}$, $\sum_j \beta_j = 1$, $\sum_j \beta_{jk}=0 \forall k$, $\sum_j \beta_{jy}=0$, and $\sum_j \beta_{jt}=0$. *A(tt)* represents the production technology. In this approach, *A(tt)* can be defined in two forms. If we encounter regular time periods (such as *MGI*), the *GTTI* will be defined as $A(tt)=\sum_{h=1} \lambda_h (L_h t)$. If not (such as *GMGI*), *A(tt)* can be defined as, for example, $A(t)=\lambda_2 L_{6\text{-}10}+\lambda_3 L_{11\text{-}12}{}^t+\quad+\lambda_t L_{t\text{-}h\text{-}T}{}^t$. where, L_t's are dummy variable for time period. This means that a dummy variable is chosen for years 6-10 and another dummy variable for years 11-12. Therefore, technical change, return to scale, and TFP growth of years 6-10 (5 years) with years 11-12 (2 years) can be compared. Also, in this approach, the trend in each of the periods is considered. This approach can be used for periods of fulfillment of plans or polices of development whose years are not similar. In this approach, the problems of degree of freedom and existence of trend are solved.

Analogous to the *GI, MGI* and *GMGI,* technical change in the *GTTI* model *(TC/GTTI)* is defined as:

$$\text{TC/GTTI}_{it} = -\left[A(tt) - A(tt-\text{h})\right]\left[\beta_a + 0.5\,\beta_{aa}\left[A(tt) - A(tt-\text{h}\right] + \sum_j \beta_{jt} \text{Ln } P_{jit} + \beta_{yt} \text{Ln } Y_{it}\right] \quad (14)$$

Finally, returns to scale is obtained from:

$$RTS/GTTI_{it} = 1/(\partial LnC_{it}/\partial LnY_{it}) = 1/(\beta_y + \beta_{yy} LnY_{it} + \sum_j \beta_{jy} Ln\, P_{jit} + \beta_{yt} A(tt)) \quad (15)$$

and *TFP* growth from:

$$FP = Y - \sum_j S_j x_j = TC/GI + Y(1-(1/RTS/GTTI)) \quad (16)$$

RESULTS AND DISCUSSION

In this paper, we compared the methods using a panel data for 20 provinces in the Iran's Barley production sector for years of 2000 to 2012. However, *MGI, GMGI*, and *GTTI* methods are presented for time series data or, at least, for panel data with small cross data, it was decided to use panel data, because *MGI, GMGI* and *GTTI* methods should compared with *GI* and *TT* methods and, finally, with the *Divisia Index* Method.

Data included price and quantity of Barley output, organic and chemical fertilizer, seed, pesticide, machinery services, irrigation water, labor, and land. To estimate Barley *Translog* cost function, we aggregated organic and chemical fertilizers, seed, and pesticide and irrigation water prices in one input price as intermediate inputs by *Tornqvist-Tiel* price index. Finally, *Translog* cost function includes only four inputs of intermediate input, machinery services (as capital input), labor, and land. Then, *Translog* cost function was estimated by four methods of *Time Trend, General Index, Modified General Index,* and *General Time Trend Index*. All regressions were estimated by nonlinear iterative seemingly unrelated method by Shazam.11 Software Package. According to Material and Method Section, we considered *TT, GI, MGI*, and *GTTI* in our attempt to estimate Barley cost function. For the comparison of these methods, first of all, Barley cost function by *TT* and *GI* was estimated. Next, technical change, return to scale, and *TFP* growth for the years 2000-2012 were calculated. To estimate Barley cost function by *MGI*, we considered a dummy variable for every year. That is, all years can be compared to each other. Then, technical change, return to scale, and *TFP* growth for years of study were computed.

The barley cost function was estimated by *GTTI* in the next step. Analogues to *MGI*, every year was chosen as a period for comparison.

Table 1
Barley TFP Growth Decomposition by TT, GI, MGI and GTTI

	Years	TT	GI	MGI	GTTI	Divisia*
TC	2000-2001	0.139	0.051	0.057	0.054	
	2001-2002	0.018	0.032	0.032	0.036	
	2002-2003	0.052	0.030	0.035	0.037	
	2004-2005	0.082	0.009	0.010	0.009	
	2005-2006	0.018	0.006	0.007	0.007	
	2006-2007	-0.061	0.001	0.001	0.001	
	2007-2008	-0.017	-0.036	-0.038	-0.043	
	2008-2009	0.003	0.001	0.001	0.001	
	2009-2010	0.048	0.049	0.057	0.051	
	2010-2011	0.097	0.093	0.111	0.096	
	2011-2012	0.079	0.062	0.073	0.076	
RTS	2000-2001	1.435	1.586	1.649	2.030	
	2001-2002	1.439	1.572	1.588	1.651	
	2002-2003	1.401	1.531	1.577	1.608	
	2004-2005	1.427	1.612	1.805	1.644	
	2005-2006	1.419	1.523	1.828	1.477	
	2006-2007	1.417	1.324	1.364	1.324	
	2007-2008	1.117	1.279	1.317	1.253	
	2008-2009	0.923	1.021	1.123	1.164	
	2009-2010	1.282	1.365	1.474	1.392	
	2010-2011	1.43403	1.404	1.615	1.769	
	2011-2012	1.33373	1.599	1.647	2.031	
TFP growth	2000-2001	0.227	0.128	0.154	0.123	0.121
	2001-2002	0.183	0.143	0.157	0.15	0.148
	2002-2003	0.201	0.182	0.218	0.215	0.211
	2004-2005	0.211	0.208	0.245	0.264	0.259
	2005-2006	0.237	0.275	0.309	0.349	0.344
	2006-2007	-0.021	0.095	0.105	0.115	0.118
	2007-2008	-0.009	-0.003	-0.003	-0.004	-0.004
	2008-2009	0.101	0.07	0.083	0.071	0.07
	2009-2010	0.231	0.122	0.146	0.148	0.149
	2010-2011	0.249	0.135	0.161	0.179	0.183
	2011-2012	0.21	0.122	0.144	0.126	0.127

*2000=100

Finally, *TFP* growth was calculated by Divisia Index. All computed *TFP* growth by *TT, GI, MGI* and *GTTI* were compared with Divisia Index. Technical change, return to scale, and TFP growth for the studied years by *TT, GI, MGI, GTTI* and *Divisia index* are presented in Table 1.

As shown in Table 1, the comparison of *TFP* growth in *TT, GI, MGI* and *GTTI* with *Divisia* shows that *GTTI* is close to Divisia index. Also, *MGI* and *GI* are rather similar to *Divisia index* but *TT* is not analogues to Divisia index. This result also shows that *GTTI* is more suitable than other indices. Given the similarity of *GI* and *MGI*, it can be proposed that *MGI* is better than GI. Results of both indices are same. Therefore, because *MGI* can be used in panel and time series data, it is better than *GI* (*GI* can only be used in panel data). Similarity of *GTTI* and *Divisia* shows that *GTTI* is the best index for calculating *TFP* growth because its results are close to *Divisia* and we can use it in time series data. Periods of time can be compared, too. Also, trend of time is considered in it. Figure 1 shows the comparison of *TFP* growth at all approaches.

For the selection of the best approaches, the estimated TFP growth of *TT, GI, MGI* and *GTTI* are compared with Divisia Index as absolute differences or differences percentage.

Table 2 shows that *TFP* growth of *GTTI* approach is very close to Divisia index. Results show that distance between Barley TFP growth of *TT, GI, MGI* and *GTTI* approaches with Divisia Index are 39.12, 17.94, 9.71 and 1.61 percent, respectively. Figure 2 shows the comparison of absolute differences of *TFP* growth of *TT, GI, MGI* and *GTTI* with *Divisia Index.*

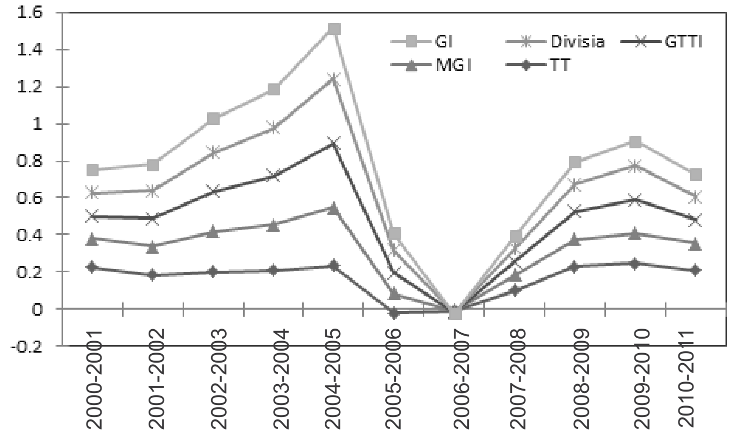

Figure 1. Barley TFP growth by TT, GI, MGI, GTTI and divisia indices

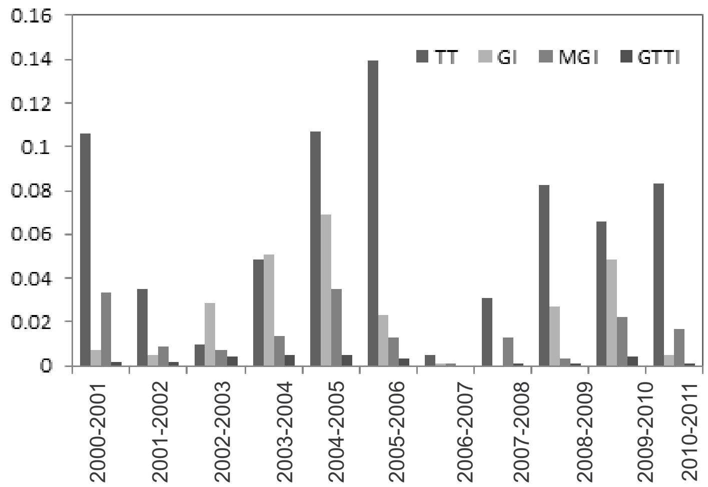

Figure 2. Comparison of Absolute Differences of TFP Growth of TT, GI, MGI and GTTI with Divisia Index

Table 2
Absolute Differences of TFP Growth of TT, GI, MGI and GTTI with Divisia Index

Years	TT	GI	MGI	GTTI
2000-2001	0.106	0.007	0.033	0.002
2001-2002	0.035	0.005	0.009	0.002
2002-2003	0.01	0.029	0.007	0.004
2004-2005	0.048	0.051	0.014	0.005
2005-2006	0.107	0.069	0.035	0.005
2006-2007	0.139	0.023	0.013	0.003
2007-2008	0.005	0.001	0.001	0.000
2008-2009	0.031	0.000	0.013	0.001
2009-2010	0.082	0.027	0.003	0.001
2010-2011	0.066	0.048	0.022	0.004
2011-2012	0.083	0.005	0.017	0.001
Average (as absolute)	0.065	0.024	0.015	0.003
Average (as percent)	39.12	17.94	9.71	1.61

CONCLUSION AND RECOMMENDATION

Finally, as the results suggest, MGI method are proposed for estimating the technical change, return to scale, and TFP growth when there are time series data or panel data with limited cross section data. Also, when only need to compare irregular time periods (for the evaluation of plans or policies), can be suggested that GMGI is the best index for estimating the technical change, return to scale, and TFP growth. When there is time series data or panel data with limited cross section data, and there is a trend in every period, can be used GTTI method for estimating the technical change, return to scale, and TFP growth.

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