Introduction

Measuring regional development levels is important in shaping micro and macro planning. Such measurements can provide insight on what to be prioritized in policies or investments while generating long-term development plans, as well as, it is possible to identify potential allocation areas for the resources and funds in the short-term. Having an idea on the level of financial, intellectual and environmental development at the regional level is beneficial for identifying reference provinces and preparing improvement policies for the undeveloped ones. Accordingly, various research can be found that evaluate the financial, intellectual and environmental aspects of regional development at the provincial level. The studies address a variety of issues, such as: identifying how effective the resources of provinces are used (Giffinger et al. 2007, Ulucan and Atıcı 2010, Giffinger and Haindlmaier 2010, Raźniak et al. 2015); evaluating life quality in order to position the well-being of countries on a provincial basis (Zhu 2001, Morais and Camanho 2011, Carboni and Russu 2015); determining the level of provinces in terms of planning services (Lahdelma et al. 2002, O’Connor 2010); assessing environmental development (Hanson et al. 2011, Sheng and Tang 2016); evaluating intellectual development (López-Ruiz et al. 2014, Nitkiewicz et al. 2014); and the measurement of competitiveness among provinces (Kourtít et al. 2013, Singhal et al. 2013a, Singhal 2013b).

Regional development is highly associated with regional prosperity. For measuring the level of prosperity (therefore development) in a given region, the banking data, as well as the economic indicators, can play a key role since they have the potential to give an idea on the financial structure of the region. Such data can reveal how the money is distributed between deposits and loans, which indirectly provides insight on the financing of the investments within the region. Provincial-level evaluations using economic indicators (such as employment level, tax revenues, imports, exports, size of the manufacturing industry in the given region, etc.) is very common in evaluating regional development levels.

In this research, we aim to incorporate a financial perspective to such evaluations using the banking data of the provinces together with other indicators. The banking data used in this study include different types of loans (personal, sectoral and non-cash sectoral loans) given out
by the bank branches and deposits (deposits and foreign exchange deposits) in the branches at provincial level. Together with indicators such as employment, participation rate in the labor force, imports, exports and several indicators on investors, we aim to come up with a multidimensional measure of regional development with respect to the economic and financial structure in 81 provinces of Turkey to reflect the level of prosperity as well. The analysis is intending to evaluate the period following the 2008 crisis for which there exists a prevalent claim that the Turkish financial sector has experienced the effects of this crisis less severely than the western economies (Yörükoğlu and Atasoy 2010, Kibritci Artar and Atılgan Sarıdoğan 2012).

Data Envelopment Analysis (DEA) is a widely used methodology to evaluate relative performance in the presence of multiple dimensions (input and output) in the intended evaluations. It is a non-parametric method applied in both micro and macroeconomic levels since its introduction by Charnes et al. (1978). DEA provides a relative measurement of efficiency for the evaluated units. This is done by comparing the evaluated unit’s performance with an efficient frontier using linear programming. In its standard use, the method measures the relative efficiency at a point in time. Because it is a relative measure, the efficiency measured at one point in time is relative to the given period’s frontier. When the evaluation period changes, the frontier also changes and, therefore, the efficiency measure in a given period may not be comparable with the next period’s measure. Building upon these facts on the DEA measures, the Malmquist Total Factor Productivity Index (MTFPI) has been developed (Caves et al. 1982, Färe et al. 1992) to measure the changes over time by considering both changes in efficiency and the shift on the frontier from one period to another.

Our evaluations intend to involve the handling of multiple indicators as well as multiple periods (2009-2014). Therefore, in measuring the provincial level financial performance, we use DEA and MTFPI to observe the movement of the measures over time. With the use of these methods, the efficiency score of each province and its change over time are measured relative to all other provinces. We interpret the findings relying on the existing measure of the Provincial Development Index (PDI) developed by Gül and Çevik (2015), classifying the provinces of Turkey into 5 clusters relying on their development level. Regarding the model design, we undertake the problem with two main approaches. The main difference between these two approaches relies on handling the factor associated with ‘loans’. The first approach sees the loans as an output factor, which relies on the idea that loans indicate investment and therefore they should be minimized. On the contrary, in the second model, we take the loans as an input factor, which relies on the idea that loans indicate debt and therefore they should be minimized.

The current research evaluates the provincial development levels in Turkey and its change over the years followed by the 2008 crisis, leaning on the idea that banking data can provide additional perspective (regarding prosperity) to the assessment of regional development. Commonly used economic factors are not ignored during evaluations, and instead, banking sector data is articulated into conventional variables, resulting in a comprehensive look at regional development. Inserting new dimensions to the problem enabled us to interpret the provinces’ development level from a different angle, by discussing the provincial-level results concerning the current classification regarding development. This provides us to observe how the provinces that are currently identified as developed or underdeveloped perform with respect to the models involving both economic and financial criteria. The results may reveal potential improvement areas and the provinces that require attention in managing regional development. The findings are also interpreted concerning the GDP change during the same period, which reveals a similar pattern in one of the approaches.

The paper is organized as follows: Section 2 presents the basics of the DEA and MTFPI methodologies. Section 3 is devoted to empirical application. We introduce the data set, discuss the model design and present the findings in this section. Finally, Section 4 concludes.
Methodology

The Malmquist Total Factor Productivity Index (MTFPI) is a Data Envelopment Analysis (DEA) based approach that allows the efficiency measurement over a certain period (Malmquist 1953, Caves et al. 1982, Färe et al. 1992). MTFPI measures the change in total factor productivity between two data points by calculating the ratios of the differences of each data point relative to the efficient frontiers of production technologies in each period. The distance function is used for the measurement. It is a nonparametric measure of productivity change which also contains information about the source of this change. The index represents the magnitude of improvement (or decrease) in the productivity of the evaluated unit from period \( t \) to \( t + 1 \). The calculation of the index relies on the evaluation of the unit in both periods \( \epsilon \) and \( t + 1 \) followed by cross evaluations of each period’s performance within the data of the other period by making use of the fundamental CCR DEA model developed by Charnes et al. (1978). To calculate the MTFPI for each unit, DEA linear programs should be solved.

Let us consider \( n \) decision-making units. We assume that each decision-making unit \( j \) for \( j = 1,2,\ldots,n \) uses \( m \) different inputs \( x_{ij} \). For \( i = 1,2,\ldots,m \) and it produces \( s \) different outputs. \( Y_{rj} \) for \( r = 1,2,\ldots,s \). Let \( \phi \) represent the efficiency score for unit \( o \). Variables \( \lambda_i \) are introduced corresponding to each decision-making unit \( (i = 1,2,\ldots,m) \) to form a Production Possibility Set (PPS) consisting of observed units, their convex combinations, scaled units (because the constant returns to scale are assumed) and outperformed units. The units on the boundary (frontier) of the PPS are defined as efficient and they attain the efficiency score of 100%, where the efficiency scores for others are measured relative to the frontier. The linear programming formulation to calculate the efficiency score of unit \( o \) is given below:

\[
\begin{align*}
\text{Max} & \quad \phi \\
\text{s.t.} & \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} \quad i = 1,2,\ldots,m \\
& \quad \sum_{j=1}^{n} \lambda_j Y_{rj} \geq \phi Y_{ro} \quad r = 1,2,\ldots,s \\
& \quad \lambda_j \geq 0 \quad j = 1,2,\ldots,n
\end{align*}
\]

In general, DEA models provide the efficiency measurement at a point in time. Let

\[
D_o^\phi(x^t,y^t) = \phi
\]

In order to measure the change from one period to another, the MTFPI is calculated for each unit. MTFPI consists of two components as Efficiency Change and Technological Change. Efficiency Change refers to the ratio of efficiency score in period \( t + 1 \) to the efficiency score in period \( t \). This measure itself is not enough to identify the change in productivity from one period to another because these scores are relative to different frontiers. Therefore, it is essential to measure the change in the frontier from one period to another. This is the second component of the MTFPI, known as technological change. The calculation of Efficiency Change \((EC)\) and Technological Change \((TC)\) components for a unit are given below:
Once both components are calculated relying on the linear programs, the MTFPI of a unit is calculated as given below (given as $x_t(x^{t+1}, y^{t+1}, x^t, y^t)$ to represent the change from period $t$ to $t + 1$).

$$EC = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}$$

$$TC = \left[\left(\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right)^2 + \left(\frac{D^t(x^t, y^t)}{D^t(x^{t+1}, y^{t+1})}\right)^2\right]^\frac{1}{2}$$

Data Envelopment Analysis (DEA) and related methodologies such as Malmquist Total Factor Productivity Index (MTFPI) can be counted in the commonly used methods to measure the relative performance of provinces regarding regional development. MTFPI enables the application of DEA in multiple periods. Among the accounted research above, several DEA and its associate methods (e.g. Super Efficiency, Fuzzy DEA, Malmquist Total Factor Productivity Index) have been applied to different types of provincial data to come up with identifying efficiency levels as well as a ranking of the provinces (for examples, see Zhu 2001, Giffinger and Haindlmaier 2010, Ulucan and Atici 2010, Morais and Camanho 2011, Kourtit et al. 2013, Ntikiewicz et al. 2014, Carboni and Russu 2015, Wang et al. 2016, Chen 2017, Li et al. 2017, Li et al. 2018, Deilmann et al. 2018, Cao et al. 2018).

Banking is one of the major areas where DEA and MTFPI are also applied (some examples include Paradi and Schaffnit 2004, Thoraneentiyana and Avkran 2009, Paradi et al. 2011, Piot-Lepelit and Nzongang 2014, Alves et al. 2020, Christopoulos et al. 2020). DEA is also used to evaluate the performance of financial institutions (Sufian 2008, Cummins et al. 2010) and microfinance institutions (Gutiérrez-Nieto et al. 2009, Biener and Eling 2011, Bassem 2014).

Results

Data

In measuring the regional development at provincial-level in Turkey, we undertook 16 variables (input and output factors). The set of factors involves economic indicators (such as employment level, tax revenues, imports, exports, size of the manufacturing industry in the given region, etc.) which are very common in evaluating the regional development levels. We benefited from the previous literature while identifying these variables (Atan et al. 2004, Düzakin 2009, López-Ruiz et al. 2014, Ntikiewicz et al. 2014, Piot-Lepelit and Nzongang 2014, Carboni and Russu 2015). Within the scope of the research, we aim to incorporate a financial perspective to the evaluations using the banking data of the provinces together with other indicators. Therefore, the set of factors also includes factors from the banking sector in the provinces of Turkey. All factors used in the study are explained below.

The factors related to the labor force (Turkish Statistical Institute 2016):

- Participation Rate in Labor Force represents the total number of people participating in the labor force in provinces between 2009 and 2014.
• **Employment Rate** represents the total number of employees hired in provinces between 2009 and 2014.

The factors related to the manufacturing industry (Turkish Ministry of Science, Industry and Technology):

• **Number of Workplaces in Manufacturing Industry** refers to the total number of active firms in the period of 2009-2014.

• **Net Sales in Manufacturing Industry** refers to net sales of firms (in Turkish Liras) by the end of the year between 2009-2014.

The factors related to the banking sector (Banking Regulation and Supervision Agency 2016):

• **Personal Loans** are cash credits used by individuals. It includes personal finance credit, vehicle loan, commercial personal finance credit, and mortgage loan.

• **Sectoral Loans** are cash loans provided for small, medium and large-sized commercial enterprises for commercial goods and services purchase as their legal entity.

• **Deposits** are bank accounts that contain money deposited to withdrawn at any time or the end of a specific term or notice. This variable refers to the sum of all types of deposit accounts (Turkish Lira) in banks of provinces.

• **Foreign Exchange Deposit (FED) Account** refers to the sum of all foreign exchange deposit accounts in banks of provinces. (Measured in Turkish Lira conversion).

• **Total TL+FED** refers to the sum of all accounts in banks of provinces (measured in US Dollars).

• **Non-Cash Sectoral Loans** are bank’s credit facility by giving guarantee and bail in favor of legal entities and appropriate credits for the sector of legal entities with the aim that they could sustain their import and export activities. Letter of guarantee, external letter of guarantee and letter of credits are included in this loan group.

The factors related to investment potentials (Central Registry Agency 2016):

• **The number of Investors** refers to the number of individual investors registered in a certain province and transacting in the stock market.

• **Total Account Balance** refers to the total account balance amount of individual investors registered in a certain province and transacting in the stock market.

The Factors associated with contribution foreign trade (Turkish Statistical Institute 2016):

• **Import** represents total annual import activities carried out in provinces (measured in Turkish Liras).

• **Export** represents total annual export activities carried out in provinces (measured in Turkish Liras).

Other Factors:

• **Tax Revenues** represent the provincial-based tax revenues (in Turkish Liras). We acquire data from the Turkish Revenue Administration (2016).

• **Energy Consumption** expresses the total electrical energy consumed throughout a year in provinces as MWh. It measures the total electricity consumption of both industry and household in the provinces. The data source is the Turkish Statistical Institute.

Note that the factors associated with banking cover three main types of banks operating in Turkey: Deposit Banks, Participation Banks (Interest-free banks) and Development & Investment Banks. All categories include sub-categories as public, private and foreign banks. The data is collected from the database of the Banking Regulation and Supervision Agency of
Turkey at provincial level for all types.

**Findings**

We establish two models in handling the factors listed above. The controversy is related to the factors related to ‘loans’. We approach these variables from two perspectives. The first approach looks at the loans as an output factor, which relies on the idea that loans indicate investment and therefore development. On the contrary, in the second model, we capture the loans as input factors, relying on the idea that loans indicate debt and therefore they should be minimized. This means that for loans, we have "the more is better" in one model and "the less is better" in another, respectively. Hence, we consider the factors associated with loans in our models as proxies of investment or indebtedment in the given region. Below, we provide the findings of both models.

**Model 1: Loans as Outputs**

The model includes 9 outputs and 7 inputs that 81 provinces and the data from 2009-2014. Inputs and outputs used in the analysis are given in Table 1. Scores for each province are presented in Table A1 of the Appendix.

Fig. 1 presents the movement of the Malmquist Total Factor Productivity Index (MTFPI) over years together with its components. The MTFPI moves along with the technological change component in the period of 2009-2014. 2009-2010 is the most progressive period, while the most decrease is observed in the 2011-2012 period. The efficiency change component is more stable, in general. This shows that the changes in MTFPI are mostly caused by the shift in the investment environment (represented by technological change), rather than the individual changes in the financial structure of provinces (that can be embodied by the efficiency change component). Taking 2009 as the base year, the relationship between technological change and MTFPI can also be observed in Table 2. While the efficiency change component decreases with the rate of 1% between the years of 2009-2014, the technological change component increases by 76%, resulting in a 75.4% increase in total productivity.

Since it is observed that technological change is dominant in increasing the total productivity, it is reasonable to observe its relationship with the GDP growth in the country over the given period. Fig. 2 presents the GDP Increase with MTFP. Generally, the GDP increase rate of

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**Table 1**

| Inputs                               | Outputs                          |
|--------------------------------------|----------------------------------|
| Participation Rate in Labor Force    | Personal Loans                   |
| Employment Rate                      | Sectoral Loans                   |
| Number of Workplace in Manufacturing Industry | Deposits (Turkish Lira)     |
| Net Profit In Manufacturing Industry | Deposits (Foreign Exchange)     |
| Import                               | Total Deposits                   |
| Export                               | Non-Cash Sector Loans            |
| Energy Consumption                   | Tax Revenues                      |
| The Number of Investors              | Total Account Balance            |
Turkey and the total factor productivity change seem to be parallel with each other. This is a sign that economic growth over the given period has a reflection on local development.

Fig. 3 shows the change in total factor productivity based on PDI. The results are interesting. Between 2002 and 2014, category 5, which consists of the least developed provinces, exhibit the largest progress. Category 4 has also experienced growth between 2010 and 2011. The least progress is observed in the most developed category. These findings may indicate that the growth in the post-crisis period seems to be deployed at different levels throughout the country. It is observed that the categories with the least developed provinces (category 4 and category 5) experience a noticeable growth relative to the other categories.

Model 2: Loans as Inputs

The model includes 6 outputs and 10 inputs of 81 provinces and the data from 2009-2014. The inputs and outputs used in the analysis are given in Table 4. The scores for each province are presented in Table A2 of the Appendix.
Fig. 4 presents the movement of the Malmquist Total Factor Productivity Index (MTFPI) over the years based on Model 2 together with its components. The largest fluctuation has been

![Graph showing the movement of GDP increase rate and MTFP over years.]

**Table 3**

**Province Classification of PDI**

| Category | Number of Provinces |
|----------|---------------------|
| Category 1 | 6 |
| Category 2 | 17 |
| Category 3 | 27 |
| Category 4 | 14 |
| Category 5 | 17 |

![Graph showing the total factor productivity change by PDI over years.]

**Fig. 3 - Total Factor Productivity Change by PDI (Model 1)**
observed between the years 2009-2011. In this model, MTFPI also moves along with the technological change rather than the efficiency change. The directions are opposite with the Model 1 findings since the factors have changed sides.

Table 5 reveals the MTFPI over the years and it indicates a decrease in terms of total productivity caused by technological change. By looking at the results in Table 2 and Table 5 together, it is possible to say that the direction of productivity depends on the treatment of loans. If loans are input factors, then there is a decline in the total productivity and vice versa. Model 2 results can also be interpreted in terms of PDI. Fig. 5 presents the movement of MTFPI with respect to different categories. Every category experiences a decrease except for

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Table 4

| Input                                | Output                                      |
|--------------------------------------|---------------------------------------------|
| Participation Rate in Labor Force    | Deposit (Turkish Lira)                      |
| Employment Rate                      | Deposit (Foreign Exchange)                  |
| Number of Workplace in Manufacturing Industry | Total Deposit                             |
| Net Profit in Manufacturing Industry | Tax Revenues                                |
| Personal Loans                       | Number Of Registered Investor to Stock Market|
| Sectoral Loans                       | Total Amount Of Account Balance             |
| Non-Cash Sector Loans                |                                             |
| Energy Consumption                   |                                             |
| Import                               |                                             |
| Export                               |                                             |

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Fig. 4 - Chart of MTFP by years (Model 2)
category 4 between 2010 and 2011 (none of the MTFPI values are over 1 except for that one). Categories 1, 2, 3 and 5 follow mainly a stationary movement over the years. For category 4, there is a spike in 2011, followed by a relatively slower growth.

| Years | Efficiency Change | Technological Change | MTFPI |
|-------|-------------------|----------------------|-------|
| 2009  | 1                 | 1                    | 1     |
| 2010  | 1.057             | 0.773                | 0.817 |
| 2011  | 1.050             | 0.742                | 0.779 |
| 2012  | 1.039             | 0.700                | 0.728 |
| 2013  | 1.044             | 0.645                | 0.673 |
| 2014  | 1.062             | 0.630                | 0.668 |

**Table 5**

Discussion

The findings presented in the previous section indicate that if the factors related to loans (personal loans, sectoral loans, and non-cash loans) are treated as outputs, growth in productivity is observed. Treating ‘loans’ as an output factor yields scores that are more closely related to the GDP growth of Turkey during the given period. Fig. 6 visualizes the MTFPI scores of Model 1 at provincial level. It is noticeable that the eastern parts of the country experience a larger growth relative to the west. Some provinces attain a very high level of change (greater than 4), mostly located in the east. The east mostly consists of category 4 and 5 provinces; however, these provinces experience the largest growth according to Model 1.
Note that Model 1 considers ‘loans’ as outputs. We approach the factors associated with loans as a proxy of investment in this model. Of course, one should note that the analysis does not solely rely on the variables associated with loans. There are other financial outputs and also an input side of the story. We have variables on employment, the size of the manufacturing industry, etc. These will also differ between high-income and low-income provinces. Nevertheless, the Data Envelopment Analysis is about accounting for such trade-offs through the multi-dimensional relativity of output/input ratios. From that perspective, in the post-crisis period, there had been an expansion in the financial system at regional level, especially for less developed provinces according to Model 1. If loans indicate investment, then there had been a growth in regional development for the less developed regions after the 2008 crisis.

On the other hand, loans can be thought of as the proxy of indebtedness as in Model 2. Fig. 7 visualizes the MTFPI scores of Model 2 at provincial level. It is observed that the majority of the provinces exhibit a decrease. When Fig. 6 and Fig. 7 are compared, it can be seen that only a few of the provinces could keep their productivity growth position. One province experiences a high level of growth and only 10 provinces attain a score greater than 1. So, when the factors associated with loans are taken as inputs, the development levels of the provinces concerning banking and finance data reveal a decrease in all categories of provinces. This, of course, contradicts with the GDP growth during the given period. Note that loans include the cash and non-cash sectorial loans. If loans indicate debt, then there had been a decline in regional development for the entire country after the 2008 crisis. One advocating loans as a means of debt would think that the decrease in the development levels in the post-crisis period is based on recovering the effects of the recession during the crisis, which would be reasonable. The contradictions between the results of the two models reveal that the idea of growth is mainly affected by depending on the opinion towards the ‘loans’ provided by the banks.

Fig. 6 - Provinces by their MTFPI Scores (Model 1)
It should also be noted that the technological change component is more effective in the change of MTFPI. The change mostly relies on the shifts on the frontier, in other words, the technological change component. Rather than individual changes in the scores (corresponding to the efficiency change component) of individual units (provinces in our case), the growth, or decline mostly, is mainly based on the shift of the frontier as a whole. In other words, from whichever perspective we approach the problem, the effects of the crisis are visible throughout the entire sample rather than the small changes at unit level.

Conclusions

In this paper, we aim to measure the provincial level financial performance of Turkish provinces using banking and finance data along with other economic indicators. For this purpose, we develop two Data Envelopment Analysis (DEA) models, mainly differing from each other in terms of handling the factors associated with ‘loans’, which turns out to affect the results when the direction of those variables is changed. The methodology is based on relativity and multi-dimensionality so that a broad perspective on regional development is aimed to be presented. As well as being a non-parametric efficiency evaluation method, DEA can also serve as an effective tool for a relative assessment in measuring regional development levels. Besides, we use a multi-period structure and the Malmquist Total Factor Productivity Index (MTFPI) method is employed to measure the change in 5 years after the 2008 crisis (between 2009 and 2014). The index is composed of two main components, namely as efficiency change and as technological change. The former represents the changes in the efficiency of individual units, whereas the latter is based on the shift in the production technology as a whole. The results are interpreted with respect to cumulative changes and to provincial development index categories. The results presented at cumulative and provincial level categories may reveal potential improvement areas and the provinces that require attention in managing regional development.

We evaluate the provincial development levels in Turkey and its change over the years, leaning
on the idea that banking data can provide an additional perspective to the assessment of regional development. Considering the banks’ key role in the financial system, the evaluations fed by the banking perspective along with the macroeconomic indicators can contribute to the way we approach regional development. The use of DEA in a mix of economic and financial/banking indicators conveys a new perspective to the assessment. Of course, banking data requires careful handling since different perspectives may lead to different directions as exposed by the findings of this research.

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### Appendix

**Table A1**

#### Model 1: Ranking Cumulative Efficiency Change of Provinces

| Rank | Provinces | Efficiency Change | Rank | Provinces | Technological Change | Rank | Provinces | MTPP |
|------|-----------|-------------------|------|-----------|----------------------|------|-----------|------|
| 1    | Şanlıurfa | 1.815             | 1    | Ordı     | 5.896                | 1    | Şanlıurfa | 8.292|
| 2    | Muğla     | 1.411             | 2    | Bitlis   | 4.783                | 2    | Ordı     | 7.588|
| 3    | Ordı      | 1.282             | 3    | Kars     | 4.713                | 3    | Bitlis   | 5.631|
| 4    | Ağrı      | 1.276             | 4    | Şanlıurfa| 4.702                | 4    | Kars     | 4.713|
| 5    | Burdur    | 1.270             | 5    | Yozgat   | 4.036                | 5    | Mardin   | 4.478|
| 6    | Denizli   | 1.235             | 6    | Kütahya  | 3.809                | 6    | Karaman  | 4.433|
| 7    | Erzurum   | 1.216             | 7    | Kars    | 3.772                | 7    | Gaziantep| 4.369|
| 8    | Karaman   | 1.211             | 8    | Mardin   | 3.763                | 8    | Karaman  | 4.351|
| 9    | Tekirdağ | 1.205             | 9    | Gaziantep| 3.679                | 9    | Denizli  | 4.318|
| 10   | Mardin    | 1.189             | 10   | Karaman  | 3.660                | 10   | Hatay    | 3.848|
| 11   | Gaziantep | 1.189             | 11   | Hatay    | 3.654                | 11   | Muğla    | 3.639|
| 12   | Bitlis    | 1.177             | 12   | Denizli  | 3.499                | 12   | Yozgat   | 3.458|
| 13   | K. Manavgat| 1.154            | 13    | Erzincan| 3.499               | 13    | Elazığ    | 3.370|
| 14   | Düzce     | 1.133             | 14    | Tokat     | 3.492              | 14    | Siirt     | 3.284|
| 15   | İzmir     | 1.129             | 15    | Osmaniye | 3.408             | 15    | Sivas     | 3.237|
| 16   | Sakarya   | 1.098             | 16    | Elazığ   | 3.370              | 16    | Kütahya  | 3.164|
| 17   | Hakkari   | 1.089             | 17    | Siirt    | 3.285              | 17    | Bilecik  | 3.039|
| 18   | Bilecik   | 1.087             | 18    | Amasya   | 3.093             | 18    | Erzincan | 3.019|
| 19   | Samsun    | 1.001             | 19    | Sivas    | 3.085              | 19    | Kırklareli| 2.910|
| 20   | Zonguldak | 1.059             | 20    | Giresun  | 3.028              | 20    | Osmaniye | 2.890|
| 21   | Hatay     | 1.053             | 21    | Çankırı  | 2.965              | 21    | Düzce    | 2.855|
| 22   | Sivas     | 1.048             | 22    | Kırklareli| 2.910          | 22    | Amasya   | 2.762|
| 23   | Beşiktepe | 1.045             | 23    | Bilecik  | 2.849              | 23    | Erzurum  | 2.718|
| 24   | Manisa    | 1.010             | 24    | Çorum    | 2.785              | 24    | Samsun   | 2.689|
| 25   | Alanya    | 1.010             | 25    | Kastamonu| 2.768             | 25    | Tokat    | 2.673|
| 26   | Ankara    | 1.000             | 26    | Van      | 2.741              | 26    | Kastamonu| 2.643|
| 27   | Antalya   | 1.000             | 27    | Adıyaman | 2.711             | 27    | Tekirdağ | 2.632|
| 28   | Ardahan   | 1.000             | 28    | Muğla    | 2.577             | 28    | Şanlıurfa| 2.479|
| 29   | Artvin    | 1.000             | 29    | Şanlıurfa| 2.574             | 29    | Bingöl   | 2.476|
| 30   | Bartın    | 1.000             | 30    | Bingöl   | 2.544             | 30    | Burdur   | 2.465|
| 31   | Bayburt   | 1.000             | 31    | Samsun   | 2.538             | 31    | Sakarya  | 2.463|
| 32   | Edirne    | 1.000             | 32    | Diyarbakır| 2.531         | 32    | Bartın   | 2.429|
| 33   | Elazığ    | 1.000             | 33    | Düzce    | 2.501             | 33    | Edirne   | 2.419|
| 34   | Eskişehir | 1.000             | 34    | Adana   | 2.446             | 34    | Zonguldak| 2.413|
| 35   | İğdir     | 1.000             | 35    | Malatya  | 2.442             | 35    | Adana    | 2.410|
| 36   | İstanbul  | 1.000             | 36    | Batman  | 2.429             | 36    | Çankırı  | 2.400|
| 37   | Karaman   | 1.000             | 37    | Edirne    | 2.419      | 37    | Diyarbakır| 2.391|
| 38   | Kars      | 1.000             | 38    | Niğde   | 2.391             | 38    | Hakkari  | 2.383|
| 39   | Kırklareli| 1.000             | 39    | Bolu     | 2.367             | 39    | Giresun  | 2.381|
| 40   | Kırklareli| 1.000             | 40    | Rize       | 2.349   | 40    | Rize     | 2.349|
### Model 1: Ranking Cumulative Efficiency Change of Provinces

| Rank | Provinces  | Efficiency Change | Rank | Provinces  | Technological Change | Rank | Provinces  | MTFPP |
|------|------------|-------------------|------|------------|----------------------|------|------------|-------|
| 41   | Kırşehir   | 1.000             | 41   | Bayburt    | 2.315                | 41   | Bayburt    | 2.318 |
| 42   | Kocaeli    | 1.000             | 42   | Zonguldak  | 2.279                | 42   | Adıyaman   | 2.289 |
| 43   | Manisa     | 1.000             | 43   | Kırklareli | 2.250                | 43   | Manisa     | 2.290 |
| 44   | Muğla      | 1.000             | 44   | Sakarya    | 2.242                | 44   | Kırklareli | 2.250 |
| 45   | Nevşehir   | 1.000             | 45   | Erzurum    | 2.236                | 45   | Ağrı       | 2.233 |
| 46   | Rize       | 1.000             | 46   | Manisa     | 2.232                | 46   | Niğde      | 2.195 |
| 47   | Trabzon    | 1.000             | 47   | Kayseri    | 2.214                | 47   | Çorum      | 2.185 |
| 48   | Tunceli    | 1.000             | 48   | Hakkari    | 2.185                | 48   | Antalya    | 2.131 |
| 49   | Yalova     | 1.000             | 49   | Tarsus     | 2.184                | 49   | Kırşehir    | 2.097 |
| 50   | Gümüşhane  | 1.000             | 50   | Antalya    | 2.131                | 50   | Bolu       | 2.058 |
| 51   | Sırt       | 0.999             | 51   | Siirt      | 2.119                | 51   | Artvin     | 2.027 |
| 52   | Isparta    | 0.997             | 52   | Kırşehir    | 2.097                | 52   | Van        | 2.002 |
| 53   | Burdur     | 0.996             | 53   | Bartın     | 2.066                | 53   | Nevşehir   | 1.994 |
| 54   | Adana      | 0.986             | 54   | Afyonkarahisar | 2.034        | 54   | Trabzon    | 1.993 |
| 55   | Uşak       | 0.982             | 55   | Afyonkarahisar | 2.034        | 55   | Kayseri    | 1.949 |
| 56   | Bingöl     | 0.972             | 56   | Nevşehir    | 1.994                | 56   | Malatya    | 1.911 |
| 57   | Şırnak     | 0.962             | 57   | Trabzon    | 1.993                | 57   | Burdur     | 1.897 |
| 58   | Çankırı     | 0.958             | 58   | Burse      | 1.941                | 58   | İğdır      | 1.884 |
| 59   | Kastamonu  | 0.956             | 59   | Burdur     | 1.902                | 59   | Yalova     | 1.862 |
| 60   | Diyarbakır | 0.948             | 60   | İğdır      | 1.844                | 60   | Bartın     | 1.826 |
| 61   | Aydın      | 0.940             | 61   | Yalova     | 1.862                | 61   | Karsıbük   | 1.800 |
| 62   | Niğde      | 0.917             | 62   | Kayseri    | 1.814                | 62   | Siirt      | 1.793 |
| 63   | Amasya     | 0.893             | 63   | Karabük    | 1.800                | 63   | Eskişehir  | 1.734 |
| 64   | Konya      | 0.891             | 64   | Ağrı       | 1.748                | 64   | Çanakkale  | 1.586 |
| 65   | Bartın     | 0.886             | 65   | Eskişehir  | 1.734                | 65   | Kütahya    | 1.575 |
| 66   | Kayseri    | 0.880             | 66   | Çankırı    | 1.653                | 66   | Akçaşy    | 1.558 |
| 67   | Bolu       | 0.869             | 67   | Akçaşy     | 1.558                | 67   | Ardahan    | 1.550 |
| 68   | Kütahya    | 0.868             | 68   | Ardahan    | 1.550                | 68   | İstanbul  | 1.507 |
| 69   | Erzincan   | 0.861             | 69   | Aydın      | 1.537                | 69   | Uşak      | 1.492 |
| 70   | Yeşuat     | 0.857             | 70   | Konya      | 1.525                | 70   | Muğla     | 1.487 |
| 71   | Osmaniye   | 0.848             | 71   | Uşak      | 1.519                | 71   | Kocaeli   | 1.468 |
| 72   | Siirt      | 0.847             | 72   | İstanbul  | 1.507                | 72   | Afyonkarahisar | 1.454 |
| 73   | Adıyaman   | 0.844             | 73   | Muğla     | 1.467                | 73   | Aydın     | 1.447 |
| 74   | Kütahya    | 0.830             | 74   | Kocaeli   | 1.466                | 74   | Ankara    | 1.396 |
| 75   | Çankırı    | 0.810             | 75   | Ankara    | 1.366                | 75   | Konya    | 1.355 |
| 76   | Çorum      | 0.784             | 76   | Isparta   | 1.237                | 76   | Isparta  | 1.235 |
| 77   | Malatya    | 0.783             | 77   | Mersin    | 1.230                | 77   | Mersin    | 1.230 |
| 78   | Giresun    | 0.779             | 78   | Balıkesir | 1.121                | 78   | Balıkesir | 1.122 |
| 79   | Tokat      | 0.765             | 79   | İzmir     | 1.012                | 79   | İzmir    | 1.144 |
| 80   | Van        | 0.730             | 80   | Gümüşhane | 0.297                | 80   | Gümüşhane | 0.297 |
| 81   | Afyonkarahisar | 0.716       | 81   | Tunceli   | 0.109                | 81   | Tunceli   | 0.109 |
## Table A2

### Model 2: Ranking Cumulative Efficiency Change of Provinces

| Ranking | Provinces         | Efficiency Change | Ranking | Provinces         | Technological Change | Ranking | Provinces | MTFPI |
|---------|-------------------|-------------------|---------|-------------------|----------------------|---------|-----------|-------|
| 1       | Ordu              | 1.835             | 1       | Ordu              | 1.961                | 1       | Ordu      | 3.597 |
| 2       | Şanlıurfa         | 1.633             | 2       | Kırıkale          | 1.424                | 2       | Kırıkale  | 1.424 |
| 3       | Kastamonu         | 1.484             | 3       | Antalya          | 1.129                | 3       | Antalya   | 1.312 |
| 4       | Tekirdağ          | 1.417             | 4       | Sivas             | 1.142                | 4       | Sivas     | 1.238 |
| 5       | Sivas             | 1.361             | 5       | Kırklareli       | 1.055                | 5       | Şanlıurfa | 1.076 |
| 6       | Bitlis            | 1.343             | 6       | Kayseri          | 1.045                | 6       | Kastamonu | 1.057 |
| 7       | Kars              | 1.283             | 7       | İstanbul         | 1.040                | 7       | Zonguldak | 1.048 |
| 8       | Kütahya           | 1.251             | 8       | Muğla            | 1.034                | 8       | İstanbul | 1.040 |
| 9       | Yozgat            | 1.220             | 9       | Kırşehir         | 0.993                | 9       | Muğla     | 1.034 |
| 10      | Samsun            | 1.217             | 10      | Zonguldak        | 0.991                | 10      | Tekirdağ | 1.032 |
| 11      | Bilecik           | 1.192             | 11      | Ankara           | 0.948                | 11      | Kırşehir  | 0.993 |
| 12      | Çankırı           | 1.183             | 12      | Yalova           | 0.940                | 12      | Kırşehir  | 0.977 |
| 13      | Tokat             | 1.178             | 13      | Nevşehir         | 0.933                | 13      | Kırklareli| 0.983 |
| 14      | Adıyaman          | 1.167             | 14      | Diyarbakır       | 0.933                | 14      | Adıyaman  | 0.948 |
| 15      | Burdur            | 1.129             | 15      | Mersin           | 0.907                | 15      | Yalova    | 0.940 |
| 16      | Elazığ            | 1.126             | 16      | Trabzon          | 0.856                | 16      | Yozgat    | 0.935 |
| 17      | Karaman           | 1.124             | 17      | Eskişehir        | 0.857                | 17      | Nevşehir  | 0.933 |
| 18      | Bayburt           | 1.114             | 18      | Rize             | 0.851                | 18      | Karaman   | 0.923 |
| 19      | Manisa            | 1.113             | 19      | Karaman          | 0.820                | 19      | Trabzon   | 0.917 |
| 20      | Erzincan          | 1.102             | 20      | Hatay            | 0.813                | 20      | Mersin    | 0.907 |
| 21      | Balikesir         | 1.097             | 21      | Edirne           | 0.808                | 21      | Elazığ    | 0.889 |
| 22      | Sivas             | 1.086             | 22      | İğdir            | 0.806                | 22      | Rize      | 0.851 |
| 23      | Erzurum           | 1.077             | 23      | İzmir            | 0.799                | 23      | Edirne    | 0.847 |
| 24      | Antalya           | 1.074             | 24      | Elazığ           | 0.789                | 24      | Hatay     | 0.846 |
| 25      | Trabzon           | 1.069             | 25      | Akşamay          | 0.780                | 25      | İğdir     | 0.837 |
| 26      | Amasya            | 1.067             | 26      | Erzurum          | 0.774                | 26      | Diyarbakır| 0.836 |
| 27      | Düzce             | 1.065             | 27      | Yozgat           | 0.766                | 27      | Erzurum   | 0.834 |
| 28      | OsmanİYE          | 1.064             | 28      | Giresun          | 0.736                | 28      | Eskişehir | 0.818 |
| 29      | Zonguldak         | 1.056             | 29      | Bayburt          | 0.733                | 29      | Bayburt   | 0.816 |
| 30      | Edirne            | 1.048             | 30      | Tekirdağ         | 0.727                | 30      | İzmir     | 0.799 |
| 31      | Hatay             | 1.041             | 31      | Kastamonu        | 0.716                | 31      | Bitlis    | 0.790 |
| 32      | Çorum             | 1.037             | 32      | Artvin           | 0.716                | 32      | Erzincan  | 0.787 |
| 33      | İğdir             | 1.036             | 33      | Erzurum          | 0.715                | 33      | Tokat     | 0.785 |
| 34      | Aydın             | 1.035             | 34      | Çorum            | 0.715                | 34      | Akşamay   | 0.780 |
| 35      | Batman            | 1.035             | 35      | Balikesir        | 0.709                | 35      | Balikesir | 0.779 |
| 36      | Ağrı              | 1.035             | 36      | Amasya           | 0.702                | 36      | Amasya    | 0.749 |
| 37      | Niğde             | 1.033             | 37      | Sirt             | 0.700                | 37      | Kars      | 0.746 |
| 38      | Afyon             | 1.022             | 38      | Gaziantep        | 0.699                | 38      | Çorum     | 0.741 |
| 39      | Sinop             | 1.014             | 39      | K.Maraş          | 0.697                | 39      | Samsun    | 0.740 |
| 40      | Bartın            | 1.005             | 40      | Kocaeli          | 0.689                | 40      | Giresun   | 0.720 |
## Table A2

### Model 2: Ranking Cumulative Efficiency Change of Provinces

| Ranking | Provinces | Efficiency Change | Ranking | Provinces | Technological Change | Ranking | Provinces | MTFPI |
|---------|-----------|-------------------|---------|-----------|----------------------|---------|-----------|-------|
| 41      | Bolu      | 1.002             | 41      | Çanakkale | 0.672                | 41      | Artvin    | 0.716 |
| 42      | Van       | 1.001             | 42      | Tokat     | 0.667                | 42      | Sirt      | 0.700 |
| 43      | Muğla     | 1.001             | 43      | Şanlıurfa | 0.659                | 43      | Kocaeli   | 0.689 |
| 44      | Yalova    | 1.001             | 44      | Adana     | 0.645                | 44      | K.Maraş   | 0.678 |
| 45      | Aksekiy    | 1.000             | 45      | Uşak      | 0.636                | 45      | Çanakkale | 0.672 |
| 46      | Ankara    | 1.000             | 46      | Aydın     | 0.623                | 46      | Gaziantep | 0.658 |
| 47      | Ardahan   | 1.000             | 47      | Denizli   | 0.623                | 47      | Aydın     | 0.645 |
| 48      | Artvin    | 1.000             | 48      | Bursa     | 0.616                | 48      | Adana     | 0.638 |
| 49      | Bingöl    | 1.000             | 49      | Samsun    | 0.608                | 49      | Uşak      | 0.636 |
| 50      | Çanakkale | 1.000             | 50      | Mardin    | 0.603                | 50      | Bursa     | 0.616 |
| 51      | Gümüşhane | 1.000             | 51      | Hakkari   | 0.600                | 51      | Sakarya   | 0.618 |
| 52      | Hakkari   | 1.000             | 52      | Biliss    | 0.590                | 52      | Bursa     | 0.616 |
| 53      | İsparta   | 1.000             | 53      | Karsı     | 0.581                | 53      | Hakkari   | 0.600 |
| 54      | İstanbul  | 1.000             | 54      | Van       | 0.574                | 54      | Düzce     | 0.593 |
| 55      | İzmir     | 1.000             | 55      | Şırnak    | 0.569                | 55      | Van       | 0.574 |
| 56      | Karabük   | 1.000             | 56      | Muğla     | 0.562                | 56      | Batman    | 0.574 |
| 57      | Kırıkkale | 1.000             | 57      | Düzce     | 0.556                | 57      | Ağrı       | 0.572 |
| 58      | Kırşehir   | 1.000             | 58      | Batman    | 0.556                | 58      | Adıyaman  | 0.571 |
| 59      | Kocaeli   | 1.000             | 59      | Ağrı       | 0.553                | 59      | Şırnak    | 0.569 |
| 60      | Mersin    | 1.000             | 60      | Bolu      | 0.551                | 60      | Muğla     | 0.562 |
| 61      | Muğla     | 1.000             | 61      | Bolu      | 0.550                | 61      | Afyon     | 0.557 |
| 62      | Nevşehir   | 1.000             | 62      | Malatya   | 0.549                | 62      | Bolu      | 0.552 |
| 63      | Rize      | 1.000             | 63      | Afyon     | 0.546                | 63      | Malatya   | 0.548 |
| 64      | Sirt      | 1.000             | 64      | İsparta   | 0.542                | 64      | Denizli   | 0.547 |
| 65      | Şırnak    | 1.000             | 65      | Konya     | 0.531                | 65      | İsparta   | 0.542 |
| 66      | Tunceli   | 1.000             | 66      | Kilsı     | 0.506                | 66      | Çankırı   | 0.541 |
| 67      | Uşak      | 1.000             | 67      | Sinop     | 0.500                | 67      | Mardin    | 0.526 |
| 68      | Malatya   | 0.999             | 68      | Adıyaman  | 0.489                | 68      | Bilecik   | 0.519 |
| 69      | Bursa     | 0.998             | 69      | Ardahan   | 0.489                | 69      | Konya     | 0.509 |
| 70      | Kilis     | 0.996             | 70      | Osmaniye  | 0.477                | 70      | Osmaniye  | 0.507 |
| 71      | Adana     | 0.990             | 71      | Bingöl    | 0.474                | 71      | Sinop     | 0.507 |
| 72      | Giresun   | 0.981             | 72      | Çankırı   | 0.457                | 72      | Kilis     | 0.504 |
| 73      | K.Maraş   | 0.972             | 73      | Sakarya   | 0.453                | 73      | Ardahan   | 0.489 |
| 74      | Konya     | 0.958             | 74      | Bilecik   | 0.435                | 74      | Kütahya   | 0.488 |
| 75      | Eskişehir | 0.955             | 75      | Manisa    | 0.431                | 75      | Manisa    | 0.479 |
| 76      | Gaziantep | 0.943             | 76      | Nigde     | 0.413                | 76      | Bingöl    | 0.474 |
| 77      | Kayseri   | 0.935             | 77      | Bartın    | 0.399                | 77      | Nigde     | 0.427 |
| 78      | Kırklareli | 0.913             | 78      | Kütahya   | 0.390                | 78      | Bartın    | 0.401 |
| 79      | Diyarbakır | 0.897             | 79      | Karabük   | 0.384                | 79      | Karabük   | 0.384 |
| 80      | Denizli   | 0.879             | 80      | Gümüşhane | 0.165                | 80      | Gümüşhan e | 0.165 |
| 81      | Mardin    | 0.871             | 81      | Tunceli   | 0.004                | 81      | Tunceli   | 0.004 |

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### Province Classes in PDI

| Categories | Provinces |
|------------|-----------|
| **Category 1** | Ankara, Antalya, Bursa, İstanbul, İzmir, Kocaeli |
| **Category 2** | Adana, Aydın, Balıkesir, Çanakkale, Denizli, Eskişehir, Gaziantep, Hatay, Kayseri, Konya, Manisa, Mersin, Muğla, Sakarya, Samsun, Tekirdağ, Trabzon |
| **Category 3** | Afyonkarahisar, Amasya, Bartın, Bilecik, Bolu, Burdur, Çorum, Diyarbakır, Düze, Edime, Elazığ, Erzurum, Isparta, K. Maraş, Karabük, Karaman, Kırıkkale, Kırklareli, Kütahya, Malatya, Nevşehir, Rize, Sivas, Şanlıurfa, Uşak, Yalova, Zonguldak |
| **Category 4** | Aksaray, Artvin, Çankırı, Erzincan, Giresun, Kastamonu, Kirşehir, Mardin, Niğde, Ordu, Osmaniye, Sinop, Tokat, Tunceli |
| **Category 5** | Adıyaman, Ağrı, Ardahan, Batman, Bayburt, Bingöl, Bitlis, Gümüşhane, Hakkari, Iğdır, Kars, Kilis, Muş, Siirt, Şırnak, Van, Yozgat |

*Fig. A1 - Classified Provinces of Turkey*