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The Effect of Innovation on Employment: An ARDL Bounds Testing Approach for Turkey[1]

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İnovasyonun İstihdam Düzeyine Etkisi: Türkiye İçin Bir ARDL Sınır Testi Yaklaşımı[2]

Abstract

Since the acceleration of technological advancements, many studies have been done in the economics literature on the direction and extent of the relationship between innovation and employment. The findings of these studies indicate that there is no unanimity among the researchers on an innovation-employment relationship. Based on annual data for the 1990-2018 period, this paper investigates the effect of innovation on employment in the Turkish economy using the ARDL bounds testing approach. The results obtained from the analysis show that exports of high-tech products, R&D expenditures, and changes in the number of firms positively affect employment, whereas, contrary to expectations, the number of domestic patent applications seems to affect it negatively.

Keywords : Innovation, Employment, ARDL, Turkey.

JEL Classification Codes : E24, F16 J23, O31.

Öz

Teknolojik ilerlemelerin ivme kazanması ile birlikte iktisadi literatürde inovasyon ve istihdam ilişkisinin yönü ve boyutları konusunda birçok araştırma yapılmıştır. Yapılan araştırmalardan elde edilen sonuçlar, inovasyon ve istihdam ilişkisi bakımından araştırmacılar arasında tam bir fikir birliğine ulaşılmadığını göstermektedir. Bu çalışmada Türkiye ekonomisi ekseninde inovasyon faaliyetlerinin istihdam düzeyi üzerindeki etkileri ARDL Sınır Testi yöntemi kullanılarak araştırılmıştır. Değişkenlere ilişkin yıllık veriler 1990-2018 dönemini kapsamaktadır. Araştırma sonuçlarına göre, yüksek teknolojili ürün ihracatı, Ar-Ge harcamaları, işletme sayısındaki değişim parametreleri istihdam düzeyine pozitif katkı yapmaktadır. Buna karşılık, beklentilerin aksine, yurt içi patent başvuru miktarı istihdam düzeyini negatif etkiler görünmektedir.

Anahtar Sözcükler : İnovasyon, İstihdam, ARDL, Türkiye.

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1 *This study is the updated version of the paper presented in Turkish at the 4th International Entrepreneurship, Employment and Career Congress.*

2 *Bu çalışma, 4. Uluslararası Girişimcilik, İstihdam ve Kariyer Kongresi'nde Türkçe sunulan bildirinin güncellenmiş halidir.*

1. Introduction

Keeping employment at acceptable levels is among the main objectives of economic policy. The relationship between technological developments and employment are discussed extensively on economic platforms. Industrial progress in the last half-century, the emergence of machines, and the use of computers that increase the demand for skilled workers are known examples of the effects of technological change on the labour force. Today, while the life cycle of the products is shortening, production technologies are becoming more and more frequently changeable. Investing in innovation increases companies' capabilities by enabling them to compete in international markets while making it easier to adopt new technologies that increase labour productivity. In this respect, the innovation process defined by introducing new or significantly improved products, processes, and organizational structures is among the critical determinants of accelerating or sustaining economic growth (Cirera & Sabetti, 2016: 2). Although there is a consensus in the literature about the positive contributions of innovation to productivity and economic growth, there is no consensus regarding the effects of innovation on employment. While the findings of some studies show a positive relationship between employment and innovation, some other studies indicate the presence of a negative relationship between the two variables. Among the determining factors of these differences is the type of innovation, research sample size, economic development levels of the countries examined, degree of competitiveness, differences in labour skills, and the research methods implemented.

Since new approaches to product design are expected to impact demand for goods positively, the idea that labour demand would increase is plausible. In addition, one can say that there is no consensus on the idea that new production methods would decrease labour demand, hence reducing the employment level. This is because technological advancements would, on the one hand, increase the number of unemployed persons in some areas. Still, they would have expansionary effects on employment in some other areas through new investments due to decreasing costs and increasing demand for products.

In this regard, we observe that the bulk of the studies on innovation-employment relationships use relatively firm or sectoral data. In contrast, the number of those studies using macro variables is pretty limited. However, it is essential to note that the effects of innovation at the firm level might differ from sectoral level effects. It might be challenging to monitor firms' entry and exits, and new business environments might develop. At the same time, it might be impossible to differentiate market expansion from "business stealing" (Meriküll, 2008: 9).

On the other hand, more empirical studies use data from developed economies where technologically more advanced firms are located. On the contrary, those firms operating in the developing or emerging market economies produce mainly products with low value-added or operate simply as a subcontractor of foreign firms. Therefore, they differ from firms from developed countries (Meriküll, 2008: 5).

In light of this, our study investigates the effects of innovation indicators on employment levels in Turkey's economy based on annual data from 1990-2018. ARDL Bound Test approach has been adopted in the study as econometric analysis. The study is expected to contribute to the literature basically in three ways. First, we use data from an emerging market economy to see a difference between emerging and developed economies. Secondly, we utilize macroeconomic variables in the analysis, which is rare in the existing literature. The third contribution of the study has something to do with the method we implement to test the effect of employment on inflation.

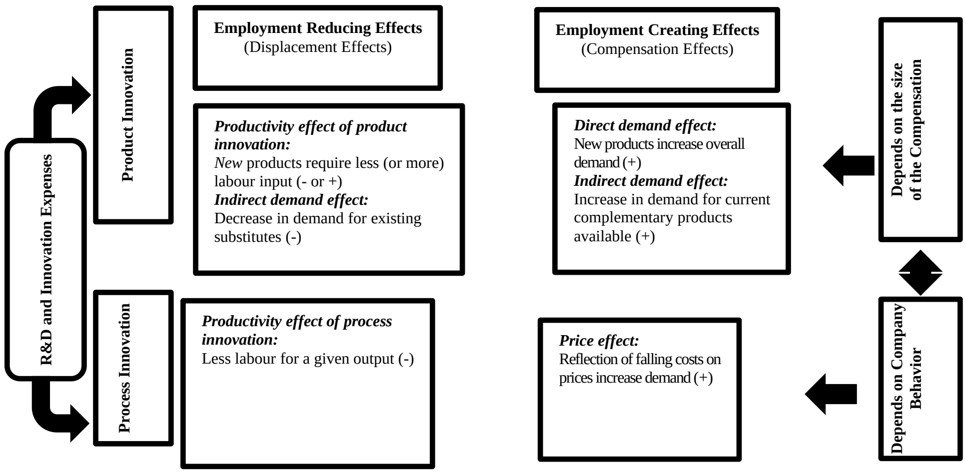
2. The Relation Between Innovation and Employment

Innovation comes out from investments of economic units in productive knowledge, management practices, and organizational decisions. The ultimate aim of these investments is to introduce innovations that positively affect the company's performance by increasing productivity, sales, earnings, or profitability. However, there is uncertainty regarding the extent to which companies can transform their productive investments into innovation and whether these innovation outcomes will affect the performance of companies. In other words, innovation is a risky phenomenon. This is because, in the beginning, it is impossible to know for sure whether or not a new product, process, or organizational change will lead to successful operations and profitable products that could be sold in the market. This is especially true for the countries where key complementary factors such as skills, managerial, and organizational or technological capabilities are too weak to support innovation (Cirera & Sabetti, 2016: 4).

There are four types of innovation within the framework of the Oslo Guide: product innovation, process innovation, organizational innovation, and marketing innovation (Fazlıoğlu et al., 2019: 441). However, when evaluated from an evolutionary point of view, one can talk about two main types of innovation: *process innovation* and *product innovation* (Massini, 2016: 7). Product innovation refers to newly developed or substantially improved goods or services. In this case, one can talk about differences in the main features of the firm's new products as opposed to its previous products (Fazlıoğlu et al., 2019: 441). Process innovation is characterized by the desire to increase productivity or reduce costs by either saving on labour, capital, or a combination of both. Process innovation comes out mostly with investments in capital goods containing a new technology. Generally, higher productivity and job losses are expected after a process innovation. On the other hand, introducing new products or replacing, adapting, or improving an existing product increases the variety and quality of the goods and creates new markets that result in higher production and employment (Massini, 2016: 7).

As shown in Figure 1 below, both types of innovation can be associated with employment reducing (*displacement effects*), labour-saving effects, and job-creating effects (*compensation effects*).

Figure: 1
Innovation - Employment Relationship



Source: Dachs & Peters, 2013: 3; Harrison et al., 2008: 37.

The effects of process innovation on employment for a given enterprise are closely related to productivity changes. Introducing new production processes causes productivity increases because the production process enables firms to get the same output level with less labour input and lower unit costs. The scope of productivity effect of the negative displacement effect depends on the existing production technology, the hence marginal rate of technical substitution between factors, and the direction of technological change (Dachs & Peters, 2013: 3).

However, if labour productivity (and other factors) is transferred to prices, then demand goods, followed by derived demand for labour, hence employment will increase (compensation effect), thereby reducing marginal cost. The outcome of these two balancing (compensation) results is generally expected to be positive. The magnitude of the impact will depend on the price elasticity of demand (Garcia *et al*., 2004: 2), price falls, and the extent of competition as well as the behaviour and relative strength of different representatives, including managers of the firms and the labour unions (Dachs & Peters, 2013: 3).

Product innovation promotes employment growth mainly through demand. When a new product successfully enters the market, innovation causes new demand for the enterprise’s product. This direct demand effect may emerge from overall market expansion or may result in losses incurred by the firm’s competitors. The magnitude of the compensation effect originating from increased demand depends on the substitutability of goods and the reaction by the competitors. Besides the direct demand effect, *indirect employment effects* may also come into question at the firm level due to product innovation. First of all, indirect demand effects on the existing products of the innovating firm should be considered. Suppose the new product partially or entirely substitutes the old product. In that case, labour demand for the production of the old product is reduced, and the overall effect becomes uncertain for the business enterprise which made the innovation.

On the other hand, in the case of complementary demand relationships, the new product will also cause an increase in demand for the existing products. Hence employment will increase further. Secondly, compared to the old product, the same amount of output of the new product may be produced at higher or lower productivity levels. In other words, the new product may imply a change in the production method and the input mixture; this may also either reduce or increase labour input (Dachs & Peters, 2013: 4; Harrison *et al*., 2008, 5). Product innovations may also have productivity effects, even if they are not associated with simultaneous process innovations. The new or improved product may imply a change in the production method and input mix, reducing or increasing labour requirements. Therefore, empirical investigation is needed to determine the extent and direction of these effects. However, they are likely to be smaller than the positive compensation effects from increased demand for a firm’s products. The importance of such increases in demand will depend on the nature of competition and how long it will take the rivals to react to the new products. In addition, since the new products are likely to decrease the firm’s sales to a certain degree, compensation effects may get smaller (Harrison et al., 2008, 5).

Since productivity increase result from the process, innovation means producing the same output level using less labour input, reducing employment. However, this also means a fall in unit costs. Based on the company’s degree of competition, a cost reduction will likely lead to lower prices. This will positively affect demand and, therefore, production and employment. The demand elasticity of the products significantly determines the magnitude of the compensation effect. It also depends on the representatives within the firm and the nature of the competition. For instance, while labour unions try to turn any earning received from innovation into an increase in labour payments, the firm’s managers may use its market power to increase their earnings. Both behaviours can reduce and override the compensation effect (Harrison et al., 2008: 5).

Additional employment effects of innovations can also occur at the sectoral or macro level. For instance, process innovations can affect employment in companies close to the first production stage. The innovative company is directly promoted to acquire new machines to upgrade the production process. Indirect effects occur if the innovating company can increase its productivity. Benefiting from this production increase, supplier companies can also increase their labour demands.

On the other hand, competing firms that cannot keep up with technological enhancement may suffer from a fall in their market share and may even exit from the market. Innovations in production can also lead to externalities in both ways, positive or negative, for other companies operating in the same industries and some other industries. The intensity of indirect demand effects over the other companies depends mainly on demand relationships. Although the innovative company is, in principle, faced with unlimited demand, the overall demand, in general, is limited at the sectoral level. Product innovation creates negative externalities if the innovative company expands production at the expense of other companies' existing products. In this respect, indirect demand effects on the products called "stealing business" or "business thievery" should be considered at the sectoral and macro levels. On the contrary, in the presence of complementary demand, product innovation will increase the demand for existing products of other companies. It can even trigger the development of new complementary products (Dachs & Peters, 2013: 4).

On the other hand, in a competitive world, as stated in Say's law, within the framework of the classical approach, "each supply creates its demand,"[3] and technological change ultimately enters the process of self-regulation. In addition, the compensation mechanism "through the fall of prices" has been proposed many times by both Neoclassical economists and modern theorists in the history of economic thought. In addition, in a world where competitive convergence is not instant, innovative entrepreneurs can make extra profits in the process of the time-lag between decreases in costs due to technological progress and the fall in prices. Classical and Neoclassical economists assume that employment will improve after these profits are used in new products and business areas (Vivarelli, 2007: 2-3).

However, the functionality of this mechanism on which Say's law is based has been criticized for not considering the existence of demand contractions. According to Keynes, difficulties associated with some components of effective demand, such as lower marginal capital efficiency, may postpone spending decisions and further reduce demand elasticity. The compensation mechanism does not work in such cases, and technological unemployment is no longer a temporary problem. Moreover, the effectiveness of the

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[3] *However, we should underline that, contrary to what is widely believed, the true form of the Say's law is not "every supply creates its own demand." In reality it simply says "supply of A creates demand for B" implying that you have to produce and offer something before you demand something else. It is, therefore, as far as its widely known -but not true- form is concerned, something of a "famous wrong but known as right." In fact, it was not J.B. Say himself who argued "supply creates its own demand," but it was reformulated in these words, not surprisingly, by John Maynard Keynes who had a mentality conflict with the Classical school. It is amazing to see how far someone's theory can be reformulated by someone else to mean something quite different from its original meaning yet become so widely accepted in its distorted form that no one questions its arguments anymore. This can only be explained by the fact that Keynesian approach became so dominant for decades following the Great Depression that no one dared to question its arguments. For a more detailed discussion, see Skousen (2016).*

compensation mechanism through price falls depends on the validity of the perfect competition hypothesis. If the dominant oligopolistic structure, the compensation effects are severely weakened since cost minimization is no longer compulsory and is not transformed to falling prices. In addition, the transformation of increased profitability of companies into new investments is not warranted. When pessimistic expectations prevail in companies, the transformation of accumulated profits created by innovation into investments can be postponed due to the "animal spirits" in Keynes' words (Vivarelli, 2014: 128).

In line with these evaluations, the following section reviews some of the studies contributing to the literature regarding the impact of innovation activities on employment.

3. Literature Review

Even though there are also macroeconomic studies, the primary studies examining the relationship between innovation and employment in the literature are firm-based or sector-based. The existing literature on the innovation-employment relationship is summarized in Table1 below.

Table: 1
Summary of the Literature

Author(s), Year	Country, Period (s), Analysis Level	Method	Results
Piva & Vivarelli (2005)	Italia 1993-1997 Firm	OLS GMM-SYS	Although it is weak, there is a positive relationship between innovation and employment.
Üçdoğruk (2006)	Turkey 1995-2000 Firm	OLS	The employment growth rates of product and process innovating companies, especially at low technology levels, are positive.
Meriküll (2008)	Estonian 1998-2000; 2002-2004 Firm and sectoral	OLS GMM	Innovation activity positively affects employment at both the company and industry level, and product innovation has a more substantial positive employment effect.
Harrison et al. (2008)	France, Germany, Spain, UK 1998-2000 Firm	OLS	The displacement effects caused by the productivity increases in the production of old products are more significant. At the same time, those associated with process innovations likely to be compensated by price falls are small. However, the effects associated with product innovations appear strong enough to repay the displacement effects significantly.
Crespi & Tacsir (2011)	Argentina, Chile, Costa Rica, Uruguay Firm	OLS	Except for Chile, product and process innovations positively affect the employment level.
Gül (2014)	Turkey 2004-2008 NUTS-2 region Firm	LS	The quality of human resources education and entrepreneurship potential positively affect employment growth. It has been observed that increasing the innovation capacity of firms has a positive effect on employment.
Karabulut (2015)	İstanbul/Turkey Firm	OLS	Product, process, and corporate innovation positively affect financial performance, customer performance, internal business process performance, learning, and growth performance.
Cirera & Sabetti (2016)	Developing Countries 2013-2015 Firm	OLS IV	Product innovation positively affects employment in the short term when it is successful and brings additional sales to the company. Besides, process innovation containing production automation does not appear to impact employment changes.
Peluffo & Silva (2018)	Uruguay 2000-2012 Firm	OLS IV	Innovation has a positive effect on employment growth and skilled labour. Compared to other innovations, productivity-improving innovations contribute more to the skill composition, skilled labour, and total employment growth. Especially product innovation has a higher positive effect on the demand for the specialized labour force.
Dachs & Peters (2013)	16 European Countries 2002-2004 Firm	WIV	Due to the general productivity increases and process innovation, there are more job losses in the companies with foreign ownership than those with domestic ownership. At the same time, the employment-creating aspect of product innovation has been more remarkable for foreign companies.

Dalgıç & Fazlıoğlu (2021)	Turkey 2003-2015 Firm	OLS	Innovation strengthens the probability of a firm’s high growth performance. Product innovation is beneficial for the manufacturing and services sector. Although process innovation is not in terms of sales, it negatively affects firm growth in terms of employment.
Jenkins (2008)	South Africa Firm	TSLS	Both trade and technology have a negative impact on employment.
Frey & Osborn (2013)	USA 2010 Firm	Logit	47% of total employment in the USA is at risk, and these professions tend to be automated over the next ten to twenty years. In addition, it has been determined that there is a susceptible structure against computerization in the service professions that have had an important share in employment in the past decades in the USA.
Berman, Bound & Griliches (1994)	USA 1959-1973; 1973-1979; 1979-1987 Sectoral	OLS	The labour-saving technological change in the US manufacturing industry in the 1980s led to a 15% drop in the employment of production workers for the period of 1979-1989. Later on, it was observed that the demand turned towards skilled workers, moving away from unskilled workers.
Jung et al. (2016)	South Korean 2010 Sectoral	CGE	Innovative activities increase total labour demand and have positive effects on economic growth. However, technological innovation improves the demand for highly skilled labour more than other labour categories.
Mehta (2016)	Indian 2000-2001; 2013-2014 Sectoral	GLS	“product innovation” on employment for different industries is positive.
Antonucci & Pianta (2002)	Eight European Countries 1994-96; 1994-99 Sectoral	OLS	Process innovations had a negative effect on employment, whereas product innovation had a weak positive impact. Total innovation expenditures contribute negatively to employment increase.
Mastrostefanoa & Pianta (2009)	10 European Countries 1994-2001 Sectoral	GLS OLS	While product innovation increases the level of employment, process innovation decreases employment. The overall effect for innovation is negative due to the dominance of process innovations.
Piva & Vivarelli (2017)	11 European Countries 1998-2011 Sectoral	GMM-SYS LSDVC	R&D expenditures contribute positively to product innovation-related employment. The positive employment effect originates from the medium and high technology sectors, while no effect has been detected in the low technology industry. Besides that, it was observed that capital formation was negatively related to employment.
Massini (2016)	Brazil 2000-2011 Sectoral	OLS	While product innovation has a negative effect on both total employment and employment share, process innovation has a positive effect, although it is not always significant.
Blien & Ludewig (2017)	Germany 1970-2004 NUTS-III Sectoral	OLS	The effect of technological change on employment may vary with the demand structure. The contribution of technological advancements to employment level is positive in the sectors with elastic demand. On the contrary, in the industries with inelastic demand, technological advances have harmful effects on employment
Evangelista & Savona (2003)	Italy 2003 Sectoral	Logit	The net effect is positive for small firms and under half of the service sectors. Innovation negatively affects large firms, capital-intensive industries, and all finance-related sectors. In general, the effect of innovation on employment was negative.
Sinclair (1981)	USA Macro	IS/LM	Positive employment compensation can occur if demand elasticity and factor substitution are sufficiently high.
Kang (2007)	South Korea 1980 -2004 Sectoral Macro	SVAR	For the 1980s, technological shocks reduced unemployment in the short run but increased it in the long run. In addition, it contributes positively to employment for both the short and long term in the 1990s.
Matuzeviciute (2017)	EU Countries 2000-2012 Macro	SGMM	Results do not indicate any significant relationship between technological innovations (the ratio of triple patent and the R&D expenditures to GDP) and the unemployment rate.

Firm-level studies (Piva & Vivarelli, 2005; Üçdoğruk, 2006; Harrison et al., 2008; Meriküll, 2008; Crespi & Tacsir, 2011; Gül, 2014; Karabulut, 2015; Cirera & Sabetti, 2016; Peluffo & Silva, 2018) found in general that endeavours toward product and process innovations positively affect employment (especially for skilled labour) though the magnitude of the layoff and compensation effects may vary. Results of some other studies (e.g., Dachs & Peters, 2013; Dalgıç & Fazlıoğlu, 2021) indicate, however, that product innovation supports employment whereas process innovation reduces it.

On the other hand, we should also note that few studies found that innovation negatively affects employment. For instance, in their research using the logit model for Italy, Evangelista & Savona (2003) found that innovation negatively affects employment when skilled labour replaces unskilled labour.

Scale is an important factor when analysing the impact of innovation on employment. This is because firm-level findings may not be compatible with those at the industry or macro level. In this context, it cannot be known in the firm-level analyses whether innovating firm gets its benefits -hence employment increases- by shutting down its competitors (“business stealing”) or if there is a net effect at the industry level. Similarly, one cannot observe the emergence of new business fields. In addition, firm-level studies are based on panel or survey data and do not represent the whole industry (Meriküll, 2008; 5; Mastrostefano & Pianta, 2009: 730). On the contrary, in addition to solving this sort of problem, industry-level analyses make it possible to determine the general effect of technological change by taking into consideration its direct effects on innovating firms as well as indirect impact on the industry, including ‘business thievery’, product substitution or differentiation, price-elastic market expansion and change (Mastrostefano & Pianta 2009: 731).

The findings of many studies looking into the innovation-employment relationship at the industry level (e.g., Berman et al., 1994; Merikull, 2008; Mehta, 2016, Jung et al., 2016) indicate that innovations have a positive effect on employment.

However, some studies reached different findings concerning the impact of product and process innovation on employment. Antonucci and Pianta (2002), Mastrostefanoa and Pianta (2009), and Piva and Vivarelli (2017) found that product innovations positively affect employment, whereas process innovations affect it negatively. Similarly, as an example of a developing economy, Massini (2016) investigated the effects of structural change on employment at the industry level in Brazil using panel data of 22 sectors. Results of the study showed that product innovations affect employment and labour force participation positively while process innovations affect it negatively. Jenkins (2008) examined the causes of high unemployment rates in South Africa, becoming a significant economic and social problem. After the decomposing change in unemployment according to Chenery type decomposition, he investigated the effect of trade and technological change on manufacturing employment’s level and skill composition by using a two-stage least squares (TSLS) estimation method. The results showed that both trade and technology have a negative effect on employment.

On the other hand, there are only a few studies in the literature investigating this issue in the framework of a macroeconomic perspective. Sinclair (1981), in this realm, highlighted the macro IS/LM model and concluded that a positive employment compensation effect might arise when demand elasticity and the substitution possibility between factors are high enough. In his analysis based on the USA data, he found strong evidence supporting compensation with the mechanism of “falling wages,” though not with the mechanism of “falling prices” (Vivarelli, 2014: 133). Kang (2007) investigated the effects of technological shocks on employment in the South Korean economy with the help of a structural VAR model. The results indicated that for the 1980s, technological shocks -while reducing it in the short run- improved employment in the long run, hence neutralizing its short-run effects in general over time. Interestingly, this effect seems to be positive both in the short and the long run for the 1990s. Matuzeviciute’s (2017) study on macroeconomic variables indicates no meaningful relationship between innovation and employment.

In summary, there is no consensus in the literature among the research results for the effects of innovations on employment. Some of them conclude that there is a positive correlation between product innovations and employment increases, whereas there is a negative correlation between process innovation and employment level. On the other hand, some conclude that innovations negatively affect employment, leaving room for further empirical research. Undoubtedly, one can think of many factors to determine these results, such as development levels of countries, the existence of a competitive structure, quality of the labour force, level of unionization, and finally, the structural status of the sector investigated.

4. Data, Model, and Method

The model we estimated in this study setting up a functional relationship between employment, patent applications, high-tech exports, changes in the number of firms, and R&D expenditures, is given below.

$$EMP_t = \beta_0 + \beta_1 PAT_t + \beta_2 HEXP_t + \beta_3 CNF_t + \beta_4 RAD_t + \varepsilon_t \tag{1}$$

The terms in Equation 1 denote the following:

EMP = The number of individuals employed,

PAT = Annual domestic patent applications,

HEXP = Exports of high-tech products in US dollars,

CNF = Annual change in the total number of firms on the national scale,

RAD = The ratio of research and development expenditures to GDP.

The data used in the analysis cover the period 1990-2018, where the raw data are compiled from the Turkish Statistical Institute (TUIK), OECD, and the World Bank data sources. The logarithmic values are used for the number of individuals employed, the number of patent applications, exports of high-tech products, and the change in the number of firms.

One of the most critical issues to be taken care of in the time series is investigating the stationary state of the series. The series must be stationary for the researcher to reach econometrically meaningful relationships between the parameters. The problem of fake regression can be encountered in a trend in the relevant variables of a time series. Therefore, the series’ deterministic (definitive) and stochastic (probabilistic) aspects should be investigated and considered. Especially in empirical studies using macroeconomic time series, stationarity tests are standard practices (Tarı, 2006: 380-381).

Unit root tests provide information about the stationarity of the series and their integration levels. The series is called zero-order integrated I(0) if they are stationary at their level values and first-order integrated I(1) if they become stationary at their first differences. Determining the integration levels of the series is important for investigating the short and long-term relationship between parameters and for the analysis method to be used (İğdeli, 2019: 2526).

In the methods adopted by Engle and Granger (1987), Johansen-Juselius (1990), and Johansen (1992), which allow the determination of a long-term relationship between the variables, they must be integrated at the same level. If the level of integration between the variables is not the same, it is not possible to establish a long-term relationship between them (Fatukasi et al., 2015: 27). If the levels of integration of the variables are not the same, the investigation on whether there is a short and long-term relationship between the time series can be done by using the ARDL (autoregressive distributed lag) method. This method offers some econometric advantages over the other single co-integration methods.

Firstly, it eliminates endogeneity problems and the inadequacy of hypothesis tests for coefficients estimated for the long term for the Engle-Granger method. Secondly, long and short-term parameters of the model can be estimated simultaneously. Thirdly, all variables are assumed to be endogenous. Fourthly, this method does not require establishing the integration level between the variables and pre-testing for unit roots (Halicioglu, 2007: 66). In this context, the ARDL method can be used not only in the case where the regressors (i.e., independent variables) are cointegrated completely I(0) or completely I(1) but also when they are partly I(0) and partly I(1) (Pesaran et al., 2001: 290). Lastly, the ARDL boundary test approach gives better results than multivariable co-integration methods in the case of small sampling (Fatukasi et al., 2015: 27).

For the ARDL method to be used, first, it is necessary to do the stationarity test for the variables. Testing for stationarity can be performed by using various tests such as Enhanced Dickey-Fuller (ADF), Dickey-Fuller GLS (DF-GLS), Phillips-Perron (PP), Elliott-Rothenberg-Stock Point-Optimal (ERS), and Ng-Perron. In the stationarity tests, the main hypothesis is a unit root (i.e., the series is not stationary). The alternative hypothesis is that there is no unit root in the series (i.e., the series is stationary). To make estimations by the ARDL method, any series included in the analysis must reach the stationary state before reaching the I(2) level. The unrestricted ARDL model can be formulated as follows:

$$\Delta EMP_t = \alpha_0 + \sum_{i=1}^{n}\beta_{1i}\Delta EMP_{t-i} + \sum_{i=0}^{n}\beta_{2i}\Delta PAT_{t-i} + \sum_{i=0}^{n}\beta_{3i}\Delta HEXP_{t-i} + \sum_{i=0}^{n}\beta_{4i}\Delta CNF_{t-i} + \sum_{i=0}^{n}\beta_{5i}\Delta RAD_{t-i} + \delta_1 EMP_{t-1} + \delta_2 PAT_{t-1} + \delta_3 HEXP_{t-1} + \delta_4 CNF_{t-1} + \delta_5 RAD_{t-1} + e_t \quad (2)$$

In Equation 2, Δ is the first difference operator, α_0 is the constant coefficient, and e is the usual white noise residuals. The left-hand side term denotes the number of individuals employed. On the right side, "δ_1-δ_5" corresponds to the long-term relationship. The "β_1-β_5" parameters with sigma represent the short-term dynamics of the model (Dritsakis, 2011: 5).

To determine the presence of co-integration in the model, it is necessary to determine the appropriate length of the lag at the beginning, where Akaike and Schwarz information criteria are used in determining the ideal lag (Esen et al., 2012: 257). To investigate the existence of long-term relationships between variables, the Pesaran et al. (2001) procedure is used. The restricted test method is based on the F-test. The F-test is the test for co-integration or testing the hypothesis that there is no co-integration between the variables. The primary and alternative hypotheses can be expressed as follows (Dritsakis, 2011: 5):

Ho: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ → there is no co-integration between variables.

Ha: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$, → there is co-integration between variables.

This can also be illustrated as FEMP (EMP | PAT, HEXP, CNF, RAD).

In the ARDL boundary test, the determination of the long-term relationship is realized by the Wald test or F statistic. Calculated F statistic is compared with the levels of significance they created asymptotically in Pesaran et al. (2001). If the calculated F statistic is below the lower limit, it is decided that there is no co-integration between the variables. On the contrary, if the calculated F statistic is higher than the upper limit of the critical values, it is accepted that there exists a long-term relationship between the variables. On the other hand, if the calculated value for the relevant variables lies between the F statistic's lower and upper critical limits, no definitive judgment can be made regarding the co-integration relationship. In this case, it is recommended to call for other co-integration methods by considering the stationarity levels of the parameters (Akel & Gazel, 2014: 31).

After determining the existence of co-integration in the model, the long-run relationship can be written as follows:

$$EMP_t = \alpha_0 + \sum_{i=1}^{n} \beta_{1i} EMP_{t-i} + \sum_{i=0}^{n} \beta_{2i} PAT_{t-i} + \sum_{i=0}^{n} \beta_{3i} HEXP_{t-i} + \sum_{i=0}^{n} \beta_{4i} CNF_{t-i} + \sum_{i=0}^{n} \beta_{5i} RAD_{t-i} + e_t \quad (3)$$

In line with the unrestricted error model estimation, the long-term elasticities are obtained by dividing one-time lagged coefficients of explanatory variables (multiplied by negative) by once lagged values of the dependent variable (Onoja, 2017:33). The error correction model regarding the variables of the ARDL model is shown as the following:

$$\Delta EMP_t = \alpha_0 + \sum_{i=1}^{n} \beta_{1i} \Delta EMP_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta PAT_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta HEXP_{t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta CNF_{t-i} + \sum_{i=0}^{n} \beta_{5i} \Delta RAD_{t-i} + \delta ECT_{t-1} + e_t \quad (4)$$

In Equation 4, EC_{t-1}, the error correction coefficient denotes the one-time lagged value of the model's residuals in which the long-term relationship between the variables is established. The error correction coefficient indicates what level of correction, in the long run, will be achieved by the divergences from the equilibrium in the short run. It is desirable to have an error correction coefficient negative and significant (Akel & Gazel, 2014: 32).

5. Findings

To perform the analysis, the stationarity test of the variables should be done in the first stage. In this study, the Phillips-Perron test method conducted the stationarity analysis as it represents a further improved version of the Augmented Dickey-Fuller (ADF) test (Asteriou & Hall, 2007: 299). The results for the unit root test are given in Table 2.

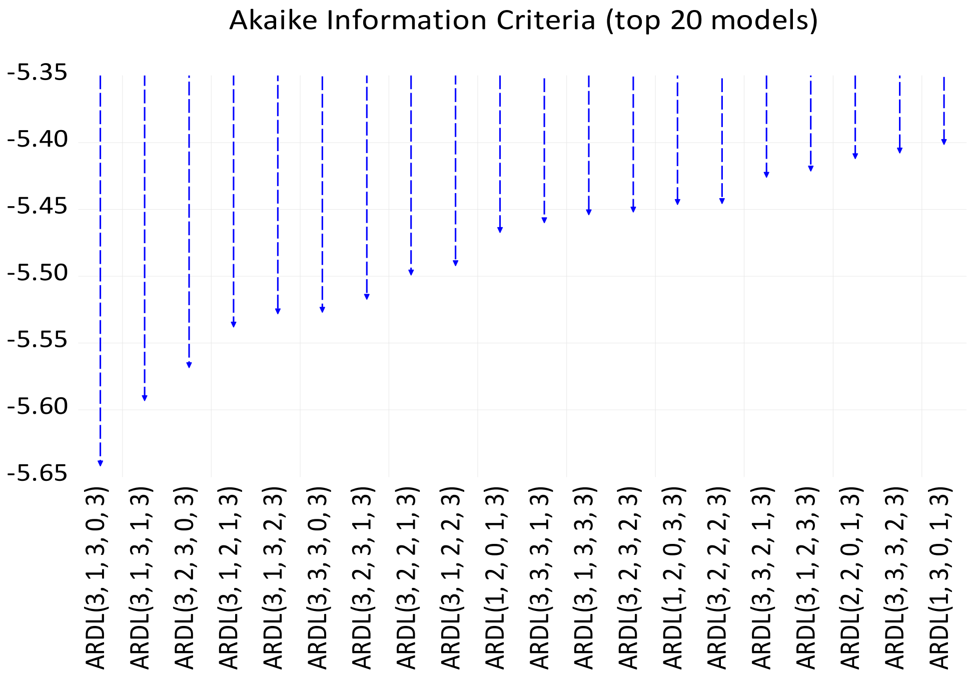
Table: 2
Unit Root Test Results

Variable	*Test Level*	*Equation Type*	*Test Statistic*		*Result*
			Constant (c)	*Const. and Trend (c&t)*	
EMP	Level	Phillips-Perron	0.7402	-1.0339	I(1)
	First Difference	Phillips-Perron	-4.8205	-5.1213	
PAT	Level	Phillips-Perron	0.1204	-1.9537	I(1)
	First Difference	Phillips-Perron	-4.1836	-4.0616	
HEXP	Level	Phillips-Perron	-2.2869	-1.7592	I(1)
	First Difference	Phillips-Perron	-5.6130	-8.6377	
CNF	Level	Phillips-Perron	-2.2932	-2.3456	I(1)
	First Difference	Phillips-Perron	-4.5747	-4.4909	
RAD	Level	Phillips-Perron	0.3843	-2.0798	I(1)
	First Difference	Phillips-Perron	-7.3425	-8.9504	

Mac Kinnon (1996) one-sided critical p values: $\tau_{0.05} = -1.954$, $\tau_{c\ 0.05} = -2.976$, $\tau_{c\ t.\ 0.05} = -3.587$

Results of stationarity analysis show that all of the variables do not show stationarity in their level values. However, they become stationary after their first difference. The fact that the variables are stationary at the I(1) level means that we can examine whether or not there are short and long-term relationships between the relevant variables. Akaike Information Criteria were used to determine the most appropriate lag length for the ARDL boundary test; ARDL (3,1,3,0,3) model proposed by the relevant information criteria was used in the analysis. Chart 1 shows the best lag length indicated by the Akaike information criteria.

Chart: 1
The Determination of Lag Length



Estimation results for the ARDL(3,1,3,0,3) model are given in Table 3.

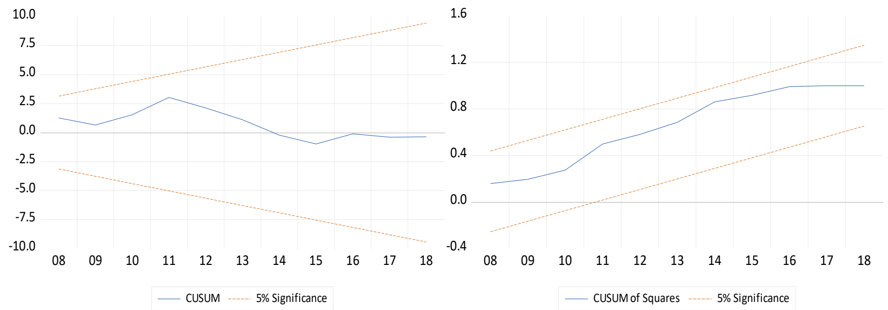
Table: 3
ARDL(3,1,3,0,3) Model Estimation Results

Dependent Variable = EMP				
Variables	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
EMP(-1)	0.7012	0.1195	5.8676	0.0001
EMP(-2)	0.0207	0.1859	0.1115	0.9132
EMP(-3)	-0.3653	0.1717	-2.1276	0.0568
PAT	0.0373	0.0294	1.2697	0.2304
PAT(-1)	-0.1010	0.0338	-2.9808	0.0125
HEXP	0.0402	0.0146	2.7481	0.0190
HEXP(-1)	0.0130	0.0178	0.7299	0.4807
HEXP(-2)	0.0535	0.0148	3.6068	0.0041
HEXP(-3)	-0.0247	0.0119	-2.0802	0.0617
CNF	0.0804	0.0169	4.7469	0.0006
RAD	-0.0981	0.0715	-1.3729	0.1971
RAD(-1)	0.1079	0.0873	1.2357	0.2423
RAD(-2)	0.2659	0.0841	3.1618	0.0090
RAD(-3)	0.3356	0.0507	6.6132	0.0000
C	5.0626	0.9404	5.3831	0.0002

Diagnostic Tests			
	Value	**Probability**	
R^2	0.9969		
F-statistics	257.74	0.0000	
Breusch-Godfrey LM Test (*F-statistic*)	1.0359	0.3936	
Heteroskedasticity Test: Breusch-Pagan-Godfrey (*F-statistic*)	0.8258	0.6381	
Ramsey Reset Test *(F-statistic)*	0.4981	0.4964	

Accordingly, the diagnostic test results for the model setup show no autocorrelation, heteroscedasticity, and specification (model setting) error. In addition, CUSUM and CUSUMSQ graphics were used to investigate the presence of a structural break in the model. As it can be seen from Chart 2, the relevant values fall within the critical limits at a 5% significance level. Therefore, the model does not have a structural break and seems stable.

Chart: 2
CUSUM and CUSUMSQ Graphics



Boundary test values investigating the co-integration relationship among the parameters used in the model are given in Table 4.

Table: 4
ARDL Boundary Test Results

	Critical Value	**Lower Bound I(0)**	**Upper Bound I(1)**
F Statistic	10%	2.75	3.99
	5%	3.35	4.77
15.9207	1%	4.76	6.67
t Statistic	Critical Value	Lower Bound I(0)	Upper Bound I(1)
	10%	-2.57	-3.66
	5%	-2.86	-3.99
-5.6570	2,5%	-3.13	-4.26
	1%	-3.43	-4.6

As shown in Table 4, F and t statistics are higher than the upper limit values. Therefore, the coefficient of EMP_{t-1} is found to be significant, and there is a co-integration relationship between the variables. Estimated long-term values are shown in Table 5.

Table: 5
Long Term Estimation Results

Dependent Variable = EMP				
Variables	***Coefficient***	***Standard Error***	***t-Statistic***	***Probability***
PAT	-0.0989	0.0227	-4.3515	0.0012
HEXP	0.1275	0.0185	6.8597	0.0000
CNF	0.1250	0.0199	6.2622	0.0001
RAD	0.9503	0.1471	6.4590	0.0000

As shown in Table 5, all coefficients are statistically significant. All variables except for patent applications seem to contribute positively to the level of employment. A 1% increase in high technology product exports leads to a 0,127% improvement in employment. Likewise, as the number of domestic firms increases, employment goes up as well: a 1% increase in the number of firms leads to a 0,125% increase in employment level. Similarly, a positive relationship between R&D expenditures and employment: a 1% increase in R&D expenditures contributes to the employment level almost at the same rate (0,95%).

Based on the long-term estimation results, one can say that the innovation-oriented efforts in Turkey turn into productivity increases and that new investments lead to increases in demand, especially for skilled labour as high-tech products sales go up at both national and international levels in a strengthened economy in terms of competitiveness. However, contrary to the theoretical expectations, there seems to be a negative, though not very strong, relationship between patent applications and employment level. Indeed, according to the estimation results, a 1% increase in patent applications seems to reduce the employment level by 0,098%. In other words, the relationship is quite weak, and its sign is contrary to the expectations. How can we explain this surprising result? One can think of two arguments in this respect.

The first argument is that, as far as the period under investigation is concerned, on average, only 20% of total patent applications could receive registration certificates; that is, most of the applications could not be converted into accepted patents. Secondly, and more importantly, it has to do with a very small portion of the patents received could be commercialized. In other words, the products that come out after receiving the patent could not be transformed into a mass-commercial production.

The error correction model estimation results carried out to determine the short-term behaviours of the co-integrated variables are given in Table 6.

Error correction model estimation results indicate that the error correction coefficient has a negative sign and is statistically significant. Accordingly, 64,3% of the deviations from the equilibrium occurring in the short run disappear until the end of the first year, hence converging to the long-run equilibrium. Additionally, a 1% increase in the high-tech product exports, which is statistically significant at a 5% significance level in the short run, causes a 0,04% improvement in the employment level.

Table: 6
Error Correction Model Estimation Results

Dependent Variable = D(EMP)				
Variables	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
C	5.0626	0.4844	10.450	0.0000
D(EMP(-1))	0.3446	0.0921	3.7414	0.0033
D(EMP(-2))	0.3653	0.1150	3.1748	0.0088
D(PAT)	0.0373	0.0200	1.8608	0.0897
D(HEXP)	0.0402	0.0111	3.6270	0.0040
D(HEXP(-1))	-0.0287	0.0088	-3.2572	0.0076
D(HEXP(-2))	0.0247	0.0088	2.7838	0.0178
D(RAD)	-0.0981	0.0491	-1.9966	0.0712
D(RAD(-1))	-0.6016	0.0710	-8.4700	0.0000
D(RAD(-2))	-0.3356	0.0394	-8.5074	0.0000
ECT(-1)	-0.6433	0.0617	-10.4187	0.0000
	Value	**Probability**		
R^2	0.9010			
F Statistic	13.6561	0.0000		

6. Conclusion

Increased competition among the economic units, firms, and economies in the development process gave way to the acceleration of innovative applications. Innovations contribute to economic development on both micro and macro levels. Nevertheless, the employment dimension of innovation as one of the main determinants of economic policy has been a subject of debate for a long time. While it is generally accepted that product innovations positively affect employment, process innovations are thought to affect them negatively. The impact of innovations on employment occurs in two different forms: displacement and compensation. In a sector where production technology is labour-intensive, increasing output with new and more productive machines through technological advancements leads to increased demand for machines at the expense of labour, reducing employment. This is called as *displacement effect* in the literature. On the contrary, the employment increasing practices of companies due to the market expansion following the release of new products are called the *compensation effects*.

It would not be an accurate assessment to assume that all technological developments have an employment-reducing effect because productivity increases and cost decreases caused by technological developments can also expand demand by pulling prices and/or wages down. Expanding output levels of the firms following increased demand paves the way for new investments, whereby employment increases may also be observed. However, introducing new products to the market may not always lead to employment growth. For instance, if the newly released products replace the old ones, an employment increase may not follow. Moreover, many other factors such as the expertise level of workers, degree of competitiveness in the market, power of the unions, demand conditions, and expectations also play an important role in the impact of product or process innovations on employment.

Classical and New Classical economists believe that technological innovations will expand employment through the spontaneous market equilibrating mechanism due to the flexibility of prices and wages. On the contrary, according to the Keynesian approach, the relationship between innovation and employment may turn negative due to various factors such as unions, imperfect competition, and uncertainties in effective demand. Accordingly, opposite or mixed results have been obtained from the empirical studies investigating the effects of innovations on employment. Nevertheless, the more dominant view is that, compared to process innovation, product innovation generally provides more employment opportunities.

In this study, the effect of innovation indicators on employment has been investigated in the Turkish economy using annual data from 1990-2018 and the ARDL Bound Test method. The results indicate that R&D activities, changes in the number of firms, and high-tech product exports positively affect employment. Based on these results, one can say that in Turkey, innovative efforts have evolved into productivity gains. It has led to improvements, especially in demand for skilled labour, with rising high-tech products in the competitively strengthened economy. Lastly, there seems to be a weak negative interaction between patent applications and employment levels. The low registration rate of national patent applications and the failure to commercialize all the patents received could explain this negative relationship. In this context, it becomes important to implement policies aiming to create skilled labour accommodating to changing demand structure due to emerging new technologies. In addition, supporting innovations that can be commercialized would help establish or sustain a competitive structure in international markets. This, in turn, will improve the balance of payments and contribute to economic growth performance positively.

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