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Effect of Economic Complexity on Unemployment in Terms of Gender: Evidence from BEM Economies

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Abstract

The present study aims to indicate whether structural transformation has provided enhancement for the disadvantaged parts of society in terms of gender or whether it has been implemented at the expense of social inequalities in 10 BEM (Big Emerging Market) economies (Argentina, Brazil, China, India, Indonesia, Mexico, Poland, South Africa, South Korea and Türkiye) in the period 1998–2019. The study also aims to understand the dynamics behind the connection between structural transformation and unemployment by comparing the results from each country. This paper also focuses on the effects of economic complexity on the breakdown of unemployment rates including female, male, youth female and youth male unemployment divisions. In the study, firstly, cross-sectional dependence is tested for all variables; secondly, the CADF test as a second-generation unit root test is applied; thirdly, the parameter constancy test is applied to each model, and then the models are estimated using the panel regression method with random coefficients. The study reveals a geographical distinction between the ten economies. Economic complexity significantly affects all types of unemployment in Poland, but it does not affect unemployment in Asian and African countries. The other result of the study is that even in Poland, the decreasing effect of ECI (Economic Complexity Index) on unemployment is different for women and men.

Keywords: Economic complexity, unemployment rate, export sophistication, structural transformation, panel data analysis, gender equality

JEL Classification: E24, F16, L16

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1. Introduction

One of the most important changes in the world economy has been related to the globalization of industries, markets and countries. Reducing trade barriers and decreasing international communication costs and access costs have accelerated this process. Among the ongoing consequences of globalization is a high level of increased foreign competition (Wiersema and Bowen, 2008; Lazonick and O'Sullivan, 1996). Under this competitive pressure, the conditions of competition have also changed radically (Wiersema and Bowen, 2008). Of course, one of the purposes of this competition is to obtain export income from the foreign trade channel.

The gain that countries obtain through foreign trade (through exports) on international markets is gaining importance. The question of how production should be carried out to maintain and even increase these earnings is being discussed again. Recent academic approaches provide a different answer to this debate. Contrary to tradition, the focus has shifted to the composition of production rather than producing more products. The nature of the productive structure, which has been historically overlooked, is important in how much of these products are produced, because not all manufactured products are equally complex. With this alternative perspective, the complexity of production stands out as a qualitative value criterion among the determinants of a country's competitiveness. In other words, the fact that countries are in cutthroat competition with each other in foreign trade changes the main question. Will the country produce large quantities or produce highly complex products? Therefore, what does complexity of production mean? The term economic complexity was coined by Hidalgo and Hausmann (2009). The complexity of a product is related to the variety of capabilities required by that product (Hidalgo, 2009). Complexity is a quantitative indicator of productive capabilities in a country. Capabilities measured by economic complexity include human capital, technological institutions and the legal system. Firm-level capabilities are associated with the know-how created by the firm, and these capabilities represent organizational capacity, the emergence of production activities, and managerial and operational capacity. Therefore, all these complex relationships affect per capita income as an element of economic complexity and wealth of countries (Felipe *et al*., 2012). Productive knowledge underlying economic complexity appears in three types: (i) embodied knowledge in tools, (ii) codified knowledge in tools, and (iii) tacit knowledge or know-how in brains. In other words, the increase in the know-how of societies depends on the specialization of individuals and the sharing of knowledge among many people. If individuals specialize, firms and countries become more complex (Balland *et al*., 2022).

Therefore, the relationship between specialization, diversification and economic complexity is extremely strong. Societies containing highly specialized individuals have more diversified knowledge, and eventually the products produced will be more diverse and complex. Besides, specialization also has a dynamic effect of producing new knowledge by using current knowledge (Balland *et al.*, 2022). With reference to Smith's view that specialization of economic agents

in various areas increases economic efficiency, Hidalgo and Hausman (2009) stated that welfare and development depend on the complexity level that emerges from different individual activities.

Furthermore, economic complexity indicates a structural transformation of economies since productive resources are moved from low-complexity to high-complexity activities (Adam *et al*., 2021; Sørensen *et al*., 2020). It is also known that structural transformation in developing countries is a reallocation process from the agricultural sector to the manufacturing sector, and this type of industrialization corresponds to the production and export of low-quality goods and services. Hence, demand for this low-skilled labour force occurs in these developing economies (Lee and Vu, 2020). Besides, the demand for high-skilled labour force increases in countries that concentrate on the production of more complex goods and services. The fact that the transformation process creates a demand for skilled labour and increases the requirement for professionals with technological competence can also be seen as an opportunity to reduce unemployment through new employment opportunities (Dao *et al*., 2017; Acemoglu and Restrepo, 2020; Graetz and Michaels, 2018). However, if human capital endowment is low in these countries, the labour force will not be flexible to respond to the needs of the labour market. Thus, the demand for a highly skilled labour force increases unemployment (Gabrielczak and Kuziemska-Pawlak, 2021). In the last two decades, new and sophisticated products have radically changed industries and sectors, leading to the disappearance of old jobs and, in parallel, the creation of new ways of working (Feldman, 2013). As such, the position of countries in the production of sophisticated goods, which is a result of their economic complexity, structural transformation paths, employment structures and unemployment levels, will affect each other in a chain.

It is not clear what kind of effects will occur on each country's labour market due to economic complexity. In addition to previous studies (Poncet and de Waldemar, 2013; Gala *et al*., 2017; A. Y. Yalta and T. Yalta, 2020; Hajimoladarvish, 2021; Adam *et al*., 2021) showing that increases in economic complexity have a slowing effect on unemployment, some studies (Hausmann *et al*., 2011; Basile *et al*., 2019; Bhorat *et al*., 2019) have found a positive and significant relationship between economic complexity and unemployment. Several studies dealing with the effects of economic complexity on employment in the context of gender have concluded that the increase in economic complexity has a positive effect on female employment (Goldin, 1990, 1991, 2000; Black and Juhn, 2000; Barza *et al*., 2020). However, other studies (Saure and Zoabi, 2009) have revealed that economic complexity reduces female labour force participation. There are also studies where there is a U-shaped relationship between employment and economic complexity in the context of gender (Luci, 2009; Lapatinas *et al*., 2021). Contrary to these findings, there are also studies showing that there is no concrete relationship between economic complexity and unemployment (Ferraz *et al*., 2017). In connection with economic complexity, it is thought that unemployment may increase as a result of substituting technology for labour in the form of automation (Postel-Vinay, 2002). Effects that create and reduce employment can occur simultaneously. In this case, the course of unemployment varies depending on which effects will outweigh

it (Mortensen and Pissarides, 1994; Aghion and Howitt, 1994). In particular, the effect of economic complexity on labour markets through foreign trade channels depends on trade-creating and trade-diverting effects. Considering that there is a complementary relationship in the production of all products in general, neighbouring countries will be able to support each other in a positive sense (Bhorat *et al*., 2019). It has been highlighted that changes in labour markets during this transformation from traditional activities to modern activities should not be neglected. Adam *et al*. (2021) revealed that the movement towards a more complex economy, in which more sophisticated and new products are developed, causes *creative destruction* processes due to both the emergence of new jobs and the destruction of existing jobs. Furthermore, this destruction was observed in the movement against machines during the Industrial Revolution (Acemoglu and Robinson, 2018). On the one hand, the emergence of unemployment (destruction) is possible due to the usage of machines and robots during the transition to modern activities; on the other hand, a new demand for a labour force (creation) that can work in complex jobs is likely to emerge as a result of integrated automation (Adam *et al*., 2021). It is probable that these two cases can be observed simultaneously in an economy. However, the characteristic of the general effects is completely related to the dynamics of economies.

Within the framework of this whole theoretical chain, the situation of young people and women, who are the most vulnerable on the labour market, come to the fore. In the global agenda, the challenges faced by young people in line with sustainable development goals are attracting increasing attention. The transition of young people to the labour market plays an important role in the socioeconomic development of countries and individuals. For this reason, it is extremely important to understand how young people are involved in employment, as well as for what reasons they cannot enter the labour market. It was argued in the Global Employment Trends for Youth Report (International Labour Organization (ILO), 2020a) that technological advances that emerged will present both challenges and opportunities for young people on the labour market. Young people around the world are worried about new technologies – especially robotics and artificial intelligence – replacing their labour opportunities. It has been stated that there is a concern that such structural transformations may increase unemployment among young people in both developed and developing countries. It is thought that the education received by the youth and the qualifications demanded by the labour market differ. This difference can place the youth at risk of unemployment. Although the global youth population increased by approximately 3 million between 1999 and 2019, the labour force participation rate decreased by 71 million people. The reasons for this decrease may be the participation of young people in education, and especially young people who are neither in employment nor in education are underlined. Most of these young people are young women. Although approximately 41 million young people are not actively looking for work, they are ready to work. The reason some of these young people are not looking for a job is because they are discouraged. Other young people are not suitable to start work immediately. Another problem faced by young people is poverty. About 13% (about 55 million) of the 429 million youth employed worldwide live in poverty, while 17% live in moderate poverty. The situation

is also not good for young people in employment. One hundred and twenty-six million young people, or a total of 30% of the working youth, are in extreme to moderate poverty despite having a job. In addition, informal unemployment among young people is quite high. More than three quarters of young people work informally (ILO, 2020a). In addition to young people, it is much more difficult for women to find a job all over the world on the basis of gender than it is for men. When the structure of female employment was examined, it was seen that women tend to work in low-quality and fragile jobs (ILO, 2022b).

These theoretical and practical determinations gave rise to the idea of examining economic complexity and the relationship between the youth and men/women. The relationship between the economic complexity and unemployment created within the framework of these determinations emerges as follows: The idea of increasing economic complexity emerges as a solution to the necessity of being at the forefront of the competition that comes with increasing globalization. To ensure economic complexity, it is recommended that countries transform their economic structures based on knowledge-based specialization. It is clear that this structural transformation will affect employment and unemployment. Therefore, the main motivation of the study is to understand how economic complexity affects gender and age-based unemployment on the labour market. For this, BEMs were chosen as the sample country set.

The reason for choosing BEM countries in the study is the thought that these countries have the power to direct all world trade, global markets and the politics-economy relationship with the increase of globalization. Investments are made in these economies, from industrial companies to pension funds. According to Garten (1998), BEMs are countries that can play a key role in the future growth of world trade, and it is necessary to understand these countries in order to understand the direction of the world's political economy. In addition, these countries are playing an increasingly important role in international finance. When we look at some indicators of global economy, we can basically understand this importance. The GDP share of the 10 BEMs in the world increased from 13.3% in 1998 to 29% in 2020, meaning more than a two-fold increase (World Bank, 2022a). We can observe the same in trade. The share of these economies in the global export of goods and services rose from 10.9% in 1998 to 23.8% in 2020 (World Bank, 2022b). On the other hand, the population of these countries rose from 2.9 billion in 1998 to 3.7 billion in 2020, which corresponds to almost half of the world population (World Bank, 2022c). Hence, it becomes a necessary question to answer whether structural change in these economies provides a potential enhancement for employment or not.

This article makes two important contributions to the relevant literature. The first contribution comes from the limited number of studies that analyse the impact of economic complexity on labour markets at the gender level (Goldin, 1990, 1991, 2000; Black and Juhn, 2000; Barza *et al*., 2020; Saure and Zoabi, 2009; Luci, 2009; Lapatinas *et al*., 2021). These studies have examined the impact of economic complexity on employment, not the impact on unemployment.

Therefore, unlike other studies, this study investigates the direct effect of economic complexity on unemployment. It also differs from the literature in that economic complexity deals with unemployment, male-female unemployment, and young female-young male unemployment rates separately. The second important contribution stems from the fact that this relationship has not been investigated before, especially for BEM countries. The article is structured as follows: In Section 2, a brief literature review is made, while the methodology and data set are explained in Section 3. Empirical results and a discussion are presented in the Section 4. In the last section of the article, the conclusion and some policy implications are given.

2. Literature Review

There is recent and limited literature on the link between economic complexity and gender unemployment. First, the studies that revealed the relationship between economic complexity and unemployment will be mentioned. Then, more specifically, studies related to labour force participation and economic complexity in the context of gender will be included.

In addition to previous studies (Poncet and de Waldemar, 2013; Gala *et al*., 2017; A. Y. Yalta and T. Yalta, 2020; Hajimoladarvish, 2021; Adam *et al*., 2021) showing that increases in economic complexity have a slowing effect on unemployment, some studies (Hausmann *et al*., 2011; Basile *et al*., 2019; Bhorat *et al*., 2019) have found a positive and significant relationship between economic complexity and unemployment.

Some studies (Goldin, 1990, 1991, 2000; Black and Juhn, 2000; Barza *et al*., 2020) covering the effects of economic complexity on employment in the context of gender have concluded that increasing economic complexity has a positive impact on female employment. On the other hand, other studies (Saure and Zoabi, 2009) suggested that economic complexity reduces women's participation in the workforce. There are also studies (Luci, 2009; Lapatinas *et al*., 2021) where there is a U-shaped relationship between employment and economic complexity in the context of gender.

The study of Poncet and de Waldemar (2013), one of the studies that found a negative relationship between economic complexity and unemployment, used data from 1997–2009 for a panel of more than 200 Chinese cities. The study results revealed that an increase in the production of complex products increases economic growth. In addition, the findings revealed that increasing economic complexity has a reducing effect on unemployment. Gala *et al*. (2017) analysed the relationship between employment and economic development in developed sectors using economic complexity and input-output matrices. The results revealed that the realization of economic growth in the long term depends on the opportunities and skills of countries to create employment in developed sectors. At the same time, it was concluded that increases in complex goods and sophisticated services positively affect the country's economic complexity. A. Y. Yalta and

T. Yalta (2020) analysed the determinants of economic complexity using the Generalized Method of Moments (GMM) approach using data from 12 MENA (Middle East/North Africa) countries for the period 1970–2015. In addition, the relationship between natural resource rents and human capital was also analysed. The findings revealed that human capital maintains a positive relationship with economic complexity, and a negative relationship was found between natural resource rent and economic complexity. Hajimoladarvish (2021) examined the relationship between economic complexity and unemployment by controlling inflation and GDP variables. In addition, this study questioned the existence of an innovation level that determines the relationship between economic complexity and unemployment. Based on a panel threshold regression using data from the period 2008–2017, a non-linear relationship was found between unemployment and economic complexity. In addition, if the innovation index was in the range of [0.456, 0.493], robots were used instead of human labour. Adam *et al*. (2021) studied the impact of economic complexity on the labour market using OECD data for the period 1985–2008 and 74 developed and developing countries for the period 1990–2010. It was revealed that the transition to a high level of economic development led to more employment and economic complexity and did not cause any unemployment. In addition, the relationship between sophisticated product knowledge and the micro-level labour market was also observed. It was concluded that countries producing more sophisticated products have higher employment levels. The study also revealed a strong negative relationship between employment and product complexity.

Among the studies that revealed that increasing economic complexity increased unemployment, Hausmann *et al*. (2011) used computing, networks and complexity techniques to create a method simply measuring economic complexity. With this methodology, an atlas was designed that collected material on each product and country. All countries in the study were included in the data set. Their findings revealed that economic complexity had a negative effect on unemployment. Bhorat *et al*. (2019) used data for the period 1995–2013 in a study that encompassed a comparison of manufacturing sectors in East and South Asia with Sub-Saharan Africa. The results showed that there had been an increase in the production of complex products in East and South Asian countries over those years, as well as an increase in employment.

In addition to the studies mentioned above, there were also studies that revealed a statistically significant and positive relationship between economic complexity and labour productivity. Basile *et al*. (2019) analysed cities in Italy using data from 2000 to 2015. They analysed the relationship between regional labour productivity and economic complexity. The effect of economic complexity measures on the distributional dynamics of labour productivity was evaluated by combining the growth regression analysis with the estimates of conditional density functions. The results revealed that ECI causes an increase in spatial productivity inequalities in both the short and long term, and there is a polarization of regional productivity levels in the long term.

As for countries such as Argentina, Brazil, Poland and Türkiye, Goldin (1990, 1991, 2000), Black and Juhn (2000), and Barza *et al*. (2020), who reached similar results, found that economic complexity reduces unemployment in a more egalitarian way. Goldin (1990, 1991, 2000) concluded that increasing specialisation and technological development positively affected women's labour force participation. Black and Juhn (2000) investigated the effect of the increase in the general skill demand that characterizes the US labour market on female employment with the help of data covering the years 1967–1998 for individuals aged 25–64 years. The findings revealed that the increasing demand for skills in the economy attracts educated women to the labour market. Barza *et al*. (2020) examined the impact of economic complexity on employment in the context of gender in Brazil. When the study findings were examined, it was revealed that with the expansion of knowledge-intensive industries, the demand for highly skilled labour increased, and gender-based wage differences decreased.

On the other hand, Sauré and Zoabi (2009), who departed from this study by suggesting that economic complexity reduces women's labour force participation, investigated the effect of specialization in sectors where female labour was intensively used in the period 1990–2007 by examining US states . The study results revealed that women's labour force participation decreased as international specialization and trade expanded in women-intensive sectors.

As one of the studies that found a U-shaped relationship between employment and economic complexity in the context of gender, Luci (2009) focused on the dynamics of gender inequality on the labour market. In the first stage, while women's participation in the labour market was high in an economy dominated by the agricultural sector, it was determined that women were excluded from labour force activities with the industrialization and urbanization activities that took place in the second stage. In the next step, there was an increase in the demand for the female labour force with the transition to skills and education-based activities. Therefore, the results indicated a U-shaped relationship between economic activities and the women's labour force participation rate. Lapatinas *et al*. (2021) examined the relationship between economic complexity and gender attitudes with the help of data from 59 countries. When the study results were discussed, a U-shaped relationship was found between knowledge and gender roles. Accordingly, economic complexity and limited knowledge restricted women's participation in employment. However, technological progress and the crossing of a certain threshold in the knowledge covered by the production of sophisticated goods have shown that it promotes more equitable participation of women on the labour market.

When the limited literature was examined, most studies encountered a positive relationship between employment in the context of economic complexity and gender. Studies that investigate the effects of economic complexity on the labour force in the context of gender are included in the literature review, but our research makes an analysis directly on unemployment in terms of gender. In addition, it differs from the literature in that it highlights that economic complexity affects unemployment, male-female unemployment, and young female-young male unemployment rates separately.

3. Data and Methodology

The present study examines the impact of economic complexity level on the unemployment rates of 10 BEMs. Within this scope, the analysis includes 10 economies of BEM, covering the period from 1998 to 2019. Detailed information about the data is given in Table 1.

Various definitions of unemployment are employed as the dependent variable and some control variables are included. Log(*unemp*), Log(*female*), Log(*male*), Log(*fyouth*) and Log(*myouth*) are the dependent variables of the models, while ECI is the core explanatory variable. The main purpose of the examination is to identify the impact of structural change in economies represented by the ECI on different forms of unemployment. Adam *et al*. (2021) used two sets of control variables, where the first group included macroeconomic indicators while the second group included institutional indicators. Inspired by Adam *et al*. (2021), macroeconomic variables are employed as the control variables. Accordingly, inflation and import are the control variables used in this study. Like Hajimoladarvish and Mozaffaripour (2021), this study also uses the GDP per capita as a control variable in the model to examine its impact on the different definitions of unemployment. However, these macroeconomic indicator control variables are restricted since a regular dataset for institutional quality of labour markets could not be reached. Table 1 depicts the variables of interest and their main descriptive statistics.

Table 1: Variables and data sources

Variable	Explanation	Data source	Obs.	Mean	Std. Dev.	Min.	Max.
Logunemp	Logarithm of unemployment, described as % of total labour force	World Bank	220	0.8655	0.2733	0.4150	1.5223
Logfemale	Logarithm of female unemployment, described as % of total female labour force	World Bank	220	0.8907	0.3036	0.4166	1.6167
Logmale	Logarithm of male unemployment, described as % of total male labour force	World Bank	220	0.8433	0.2549	0.3139	1.4368
Logfyouth	Logarithm of youth female unemployment, described as % of female labour force aged 15–24 years	World Bank	220	1.2694	0.2684	0.7627	1.8282
Logmyouth	Logarithm of youth male unemployment, described as % of male labour force aged 15–24 years	World Bank	220	1.2228	0.2417	0.4914	1.7473
ECI	Economic complexity index	OECD	220	0.6855	0.4958	–0.3500	1.9782
Inflation	Inflation, consumer prices (annual %)	World Bank	220	8.9225	13.7616	–1.8366	143.64
Logimport	Logarithm of imports of goods and services (% of GDP)	World Bank	220	1.3831	0.1714	0.9735	1.7179
Logpcgdp	Logarithm of GDP per capita (constant 2010 US$)	World Bank	220	3.8360	0.3570	2.8796	4.4575

Source: Authors' own calculation

The following models are built to examine the relationships between these variables:

$$Model\,1: Logunemp_{it} = \beta_{1i} + \beta_{2i} ECI_{it} + \beta_{3i} inflation_{it} + \beta_{4i} Logimport_{it} + \beta_{5i} Logpcgdp_{it} + u_{it} \quad (1)$$

$$Model\,2: Logfemale_{it} = \beta_{1i} + \beta_{2i} ECI_{it} + \beta_{3i} inflation_{it} + \beta_{4i} Logimport_{it} + \beta_{5i} Logpcgdp_{it} + u_{it} \quad (2)$$

$$Model\,3: Logmale_{it} = \beta_{1i} + \beta_{2i} ECI_{it} + \beta_{3i} inflation_{it} + \beta_{4i} Logimport_{it} + \beta_{5i} Logpcgdp_{it} + u_{it} \quad (3)$$

$$Model\,4: Logfyouth_{it} = \beta_{1i} + \beta_{2i} ECI_{it} + \beta_{3i} inflation_{it} + \beta_{4i} Logimport_{it} + \beta_{5i} Logpcgdp_{it} + u_{it} \quad (4)$$

$$Model\,5: Logmyouth_{it} = \beta_{1i} + \beta_{2i} ECI_{it} + \beta_{3i} inflation_{it} + \beta_{4i} Logimport_{it} + \beta_{5i} Logpcgdp_{it} + u_{it} \quad (5)$$

The theoretical expectations for the signs of coefficients of the independent variables should be noted. Firstly, an increase in the ECI is expected to increase the unemployment rate if structural changes have been made and the increase in the level of development of the economy leads to a decrease in unemployment or *vice versa*. Based on the standard Philips curve relationship, it is also expected to observe a negative relationship between inflation and unemployment rate. For the remaining control variable, namely Log(*import*), we expect to observe the effect of international trade on unemployment. Depending on the import content, this effect may be either positive or negative. If this import refers to goods used in domestic production, then the sign is expected to be negative. However, if this import substitutes domestic production, then the sign of this variable is expected to be positive. Finally, the Log(*pcgdp*) variable is expected to have a negative effect on unemployment, meaning that an increase in GDP per capita will lead to a decrease in unemployment.

To examine these models, the steps that are followed in this study are: (i) after cross-section dependence is tested for all variables, the Pesaran (2007) CADF (cross-sectionally augmented Dickey-Fuller) test, as a second-generation unit-root test, is applied to all variables, (ii) the parameter constancy test is applied to each model, and (iv) the random coefficient panel regression method is applied to each model based on the heterogeneity results of the parameter constancy test. The following section describes some theoretical explanations about these methodologies.

3.1 CADF unit root test

In the present study, cross-section dependence test results (see Appendix A) confirm the presence of cross-sectional dependence. Therefore, the CADF test, a second-generation unit root test, is employed. The CADF test is used in cases of both $T > N$ and $N > T$, where N and T refer to cross-section and time dimensions, respectively (Pesaran, 2007). Monte Carlo simulations based on various models indicate that the CADF test provides robust results even for a small N and T (Pesaran, 2007). Based on the assumption that y_{it}, which is the observation belonging to the cross-section i and the time t, is built based on the dynamic linear heterogeneous panel data model, the model in Equation (6) is used (Pesaran, 2007):

$$y_{it} = (1-\phi_i)\mu_i + \phi_i y_{i,t-1} + u_{it},\ i = 1, \ldots, N;\ t = 1, \ldots, T \tag{6}$$

In Equation (6), y_{i0} has a density function with finite mean and variance, and error term u_{it} has a structure with a single factor:

$$u_{it} = y_i f_t + \varepsilon_{it} \tag{7}$$

In Equation (7), f_t denotes an unobserved common effect and ε_{it} denotes an error term specific to the cross-section. Combining Equation (6) and Equation (7) results in Equation (8):

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{it} \tag{8}$$

where $\alpha_i = (1 - \phi_i)\mu_i$, $\beta_i = 1 - \phi_i)\mu_i$ and $\Delta y_{it} = y_{it} - y_{it-1}$. A hypothesis of this unit root test is stated below:

$$H_0 : \beta_i = 0 \tag{9}$$

$$H_1 : \beta_i < 0 \tag{10}$$

H_0 shows that all cross-sections have unit roots, while H_1 represents stationarity. As a result of the CADF test, test statistics are calculated for both cross-sections and overall panels. The test statistics for the overall panels (CIPS) are obtained by averaging the test statistics of cross-sections (Pesaran, 2007):

$$CIPS = N^{-1}\sum_{i=1}^{N} t_i(N,T) \tag{11}$$

In Equation (11), $t_i(N, T)$ refers to test statistics belonging to the cross-section i (Pesaran, 2007). Thus, Equation (11) can be written as $CIPS = N^{-1}\sum_{i=1}^{N} CADF_i$.

3.2 Random coefficient panel regression model

The random coefficient model, as an alternative to the fixed coefficient model in the panel data analysis, is used to apply stochastic specification for each cross-section. This model allows the coefficient vector to differ from unit to unit and/or over time (Hsiao and Pesaran, 2004). In the case of this kind of heterogeneity, pooled ordinary least square (OLS) regression does not provide a suitable estimation and the random coefficient model gives more appropriate results. Undoubtedly, the OLS regression would work for each cross-section unit in the case of a large enough T. However, the random coefficient model is found to be superior in the estimation of these heterogeneous units in the case of a small T (Beck and Katz, 2006).

Following Swamy (1970), the random coefficient model is represented with the matrix notation as in Equation (12) based on Poi (2003):

$$y_i = X_i\boldsymbol{\beta_i} + \epsilon_i \tag{12}$$

where $\boldsymbol{\beta_i}$ is the kx1-dimensional parameter vector specific to the cross-section *i* and is associated with a common parameter vector (Poi, 2003):

$$\boldsymbol{\beta_i} = \boldsymbol{\beta} + \nu_i \tag{13}$$

The $\boldsymbol{\beta}$ parameter, including the constant parameter, varies from cross-section unit to cross-section unit. For Equation (13), $E(v_i) = 0$ and $E(v_i)(v_i') = \sum$ hold and v_i is called "heterogeneity bias" (Yerdelen Tatoğlu, 2013). Swamy (1970) stated that it is necessary to test whether the β_i parameter vectors are constant, and that all are equal before estimating the model. Accordingly, the null hypothesis to be tested is stated in Equation (14):

$$H_0^{'} : \beta_1 = \beta_2 = \ \ldots \ = \beta_n = \beta \tag{14}$$

The hypothesis H_0' indicates that the coefficient vectors are constant, and the cross-section units examined are homogeneous. If this null hypothesis is confirmed, it will be shown that a common relationship between variables for each cross-section can be predicted. Therefore, if the null hypothesis is accepted, the random coefficient model will not need to be estimated. If the null hypothesis is rejected, it will not be possible to pool the data of each cross-section to calculate a single coefficient vector representing the relationship between the variables (Swamy, 1970). The test statistic that belongs to the parameter constancy test that Swamy developed as a Hausman-type test is formulated as follows (Yerdelen Tatoğlu, 2013):

$$\chi^2_{k(m-1)} = \sum_{i=1}^{m}\left(\widehat{\beta_i} - \overline{\beta^*}\right)'\hat{V}_i^{-1}\left(\widehat{\beta_i} - \overline{\beta^*}\right) \tag{15}$$

Empirical results and a discussion are presented in the following section based on the explanations regarding the econometric method used in the analysis in this section.

4. Empirical Results and Discussion

Based on the results obtained from the cross-section dependence test (see Appendix A), a CADF test, a second-generation unit-root test, is applied to all series.

According to the results of CADF tests in the Table 2, Inflation and Log(*pcgdp*) series are stationary at their levels, while the remaining series are stationary at their first differences. Based on these results, the models can be estimated with the random coefficient panel regression method after making all variables stationary by differencing. However, it is also necessary to search for multicollinearity problems between the explanatory variables before applying the estimation method. One way to examine multicollinearity is the examination of bivariate correlations be-

tween the explanatory variables. The absolute value of these bivariate correlations must be lower than 0.80 to avoid multicollinearity (statisticssolutions.com). Correlation values between 0.50 and 0.80 are evaluated as a medium, while values higher than 0.80 are evaluated as high (Yerdelen Tatoğlu, 2020). Another way to examine multicollinearity is to analyse the variance inflation factor (VIF) values. Accordingly, if a VIF value of a variable is higher than five, then this variable is said to be highly correlated with other explanatory variables (Kim, 2019). Hence, bivariate correlations (see Appendix B) and VIF values (see Appendix C) are calculated. It is observed that all the bivariate correlations for the explanatory variables are lower than 0.80, implying the non-existence of multicollinearity. The VIF values, which are lower than five for each variable, also confirm this result. Based on these results, it can be inferred that all independent variables can be used in the same model.

Table 2: Unit-root test results

Variables	CIPS statistics	Variables	CIPS statistics
Logunemp	–1.318	**Logmyouth**	–1.792
ΔLogunemp	–3.268***	**ΔLogmyouth**	–3.802***
Logfemale	–1.44	**ECI**	–2.476
ΔLogfemale	–3.241***	**ΔECI**	–3.638***
Logmale	–1.137	**Inflation**	–3.195***
ΔLogmale	–3.393***	**Logimport**	–2.656
Logfyouth	–1.707	**ΔLogimport**	–3.896***
Δlogfyouth	–4.191***	**Logpcgdp**	–2.826*

Notes: (***), (**) and (*) refer to 1%, 5 % and 10% significance levels, respectively. The critical values are –3.1, –2.86 and –2.73 for 1%, 5% and 10%, respectively.

Source: Authors' own calculation

Table 3: Parameter constancy test results

Models	χ^2	*p*-value
Model 1	91.58***	(0.000)
Model 2	78.48***	(0.002)
Model 3	98.47***	(0.000)
Model 4	79.42***	(0.001)
Model 5	81.75***	(0.001)

Notes: (***) refers to 1% significance levels.

Source: Authors' own calculation

As the final step before estimation, parameter constancy test results are presented in Table 3. The *p*-values are lower than 0.05 in all models, meaning that the null hypothesis of homogeneity is rejected. Hence, the coefficient vectors are estimated separately for each cross-section unit.

ECI significantly negatively affects all types of unemployment in Poland, which ranks third among the 10 countries in terms of ECI level (see Appendix D). A significantly negative effect of ECI on unemployment is found in Türkiye, Brazil and Argentina, which rank 5th, 7th and 9th, respectively (see Appendix D). Based on these findings, it can be said that the decreasing effect of ECI on unemployment is not related to the countries' ranking in terms of ECI values. No significant effect on unemployment is observed in Asian countries among the BEM economies, namely China, India, Indonesia and South Korea. It is also required to evaluate Table 4 vertically by focusing on the various definitions of the unemployment variable in terms of gender. Accordingly, ECI has a significantly negative effect on female unemployment in Argentina, Poland and Türkiye, while it has a significantly negative effect on male unemployment in Brazil and Poland. While the countries in which the ECI had a significantly negative impact on youth male unemployment are Brazil and Poland, the only country in which ECI had a significantly negative effect on youth female unemployment is Poland. Even if Poland has a decreasing effect of ECI on unemployment, this effect is higher for men than for women. All over the world, finding a job is much more difficult for women than for men. When the structure of female employment is examined, it is seen that women tend to work in low-quality and vulnerable jobs. The current global workforce participation rate of women is just under 47%, while it is 72% for men, which represents a 25% difference, with some regions having a difference of more than 50% (ILO, 2022b). Considering that women are a disadvantaged group on the labour market, it should be investigated how structural transformation affects inequalities on the labour market.

Table 4: Random coefficient panel regression estimations

Countries	Explanatory Variables	Model 1 Dependent variable: Logunemp		Model 2 Dependent variable: Logfemale		Model 3 Dependent variable: Logmale		Model 4 Dependent variable: Logfyouth		Model 5 Dependent variable: Logmyouth	
Argentina	ECI	−0.157	(0.187)	−0.189**	(0.052)	−0.108	(0.535)	−0.231	(0.089)	−0.103	(0.557)
	Inflation	0.001	(0.259)	0.001	(0.252)	0.001	(0.283)	0.000	(0.570)	0.001	(0.350)
	Logimport	−0.381**	(0.015)	−0.249**	(0.037)	−0.484**	(0.012)	−0.281**	(0.010)	−0.337*	(0.060)
	Logpcgdp	−0.130	(0.253)	−0.176*	(0.069)	−0.089	(0.446)	−0.100	(0.235)	−0.026	(0.802)
Brazil	ECI	−0.212*	(0.093)	−0.160	(0.128)	−0.271*	(0.083)	−0.175	(0.210)	−0.255*	(0.092)
	Inflation	0.001	(0.610)	0.000	(0.959)	0.002	(0.487)	0.001	(0.726)	0.002	(0.362)
	Logimport	−0.433**	(0.011)	−0.420***	(0.003)	−0.443**	(0.023)	−0.364***	(0.006)	−0.424**	(0.013)
	Logpcgdp	0.000	(0.998)	−0.040	(0.820)	0.069	(0.757)	0.015	(0.921)	0.069	(0.685)
China	ECI	−0.084	(0.412)	−0.075	(0.430)	−0.093	(0.369)	−0.082	(0.444)	−0.079	(0.444)
	Inflation	−0.001	(0.494)	−0.001	(0.543)	−0.001	(0.406)	−0.001	(0.425)	−0.001	(0.349)
	Logimport	−0.111	(0.321)	−0.139	(0.161)	−0.096	(0.416)	−0.133	(0.154)	−0.099	(0.357)
	Logpcgdp	−0.060**	(0.014)	−0.064***	(0.008)	−0.058**	(0.018)	−0.059**	(0.010)	−0.055**	(0.025)
India	ECI	−0.008	(0.849)	−0.035	(0.641)	0.001	(0.989)	−0.025	(0.711)	−0.015	(0.607)
	Inflation	0.001	(0.220)	0.001	(0.603)	0.001	(0.198)	0.001	(0.478)	0.002***	(0.002)
	Logimport	−0.087**	(0.026)	−0.194**	(0.010)	−0.054	(0.155)	−0.179***	(0.004)	−0.070**	(0.017)
	Logpcgdp	−0.023**	(0.047)	−0.044**	(0.036)	−0.016	(0.143)	−0.018	(0.291)	0.001	(0.932)
Indonesia	ECI	0.039	(0.766)	0.053	(0.639)	−0.005	(0.975)	−0.117	(0.409)	−0.114	(0.384)
	Inflation	−0.001	(0.493)	−0.002	(0.459)	−0.001	(0.656)	−0.003*	(0.074)	−0.001	(0.373)
	Logimport	0.019	(0.889)	0.079	(0.597)	−0.031	(0.827)	0.154	(0.222)	−0.020	(0.870)
	Logpcgdp	−0.120**	(0.016)	−0.173**	(0.010)	−0.079*	(0.057)	−0.210***	(0.001)	−0.111**	(0.025)
Mexico	ECI	0.004	(0.975)	−0.003	(0.979)	−0.016	(0.925)	0.158	(0.382)	0.213	(0.315)
	Inflation	−0.009***	(0.001)	−0.009***	(0.004)	−0.009***	(0.001)	−0.008***	(0.007)	−0.006**	(0.028)
	Logimport	−0.136	(0.453)	−0.157	(0.279)	−0.187	(0.377)	−0.275**	(0.015)	0.110	(0.622)
	Logpcgdp	−0.876***	(0.000)	−0.653***	(0.002)	−0.941***	(0.000)	−0.504***	(0.007)	−0.404**	(0.033)
Poland	ECI	−0.326**	(0.028)	−0.222**	(0.048)	−0.492**	(0.012)	−0.471**	(0.014)	−0.582***	(0.008)
	Inflation	−0.002	(0.343)	−0.001	(0.748)	−0.003*	(0.069)	−0.001	(0.616)	−0.001	(0.504)
	Logimport	−0.384**	(0.032)	−0.265**	(0.041)	−0.511**	(0.019)	−0.226**	(0.048)	−0.569**	(0.012)
	Logpcgdp	−0.424***	(0.006)	−0.334**	(0.031)	−0.515***	(0.001)	−0.375***	(0.003)	−0.399***	(0.005)
South Africa	ECI	−0.024	(0.794)	−0.022	(0.820)	−0.038	(0.634)	−0.033	(0.744)	−0.012	(0.900)
	Inflation	−0.001	(0.796)	−0.001	(0.592)	0.001	(0.621)	−0.001	(0.679)	0.000	(0.832)
	Logimport	−0.210	(0.101)	−0.150	(0.294)	−0.282***	(0.008)	−0.183	(0.119)	−0.241*	(0.054)
	Logpcgdp	−0.078	(0.515)	−0.172	(0.228)	0.042	(0.677)	−0.126	(0.323)	−0.058	(0.589)
South Korea	ECI	0.042	(0.766)	0.036	(0.784)	0.026	(0.857)	0.070	(0.657)	0.088	(0.573)
	Inflation	0.003**	(0.048)	0.004	(0.118)	0.003**	(0.019)	0.002	(0.239)	0.002	(0.258)
	Logimport	−0.215	(0.203)	−0.190	(0.214)	−0.240	(0.164)	−0.113	(0.425)	0.072	(0.695)
	Logpcgdp	0.203***	(0.008)	0.210**	(0.022)	0.188***	(0.009)	0.139*	(0.098)	0.161**	(0.042)
Türkiye	ECI	−0.150	(0.251)	−0.177*	(0.092)	−0.159	(0.382)	−0.179	(0.243)	−0.154	(0.334)
	Inflation	0.001*	(0.078)	0.001	(0.354)	0.002**	(0.040)	0.001	(0.353)	0.001*	(0.091)
	Logimport	−0.767***	(0.000)	−0.633***	(0.000)	−0.820***	(0.000)	−0.469***	(0.000)	−0.698***	(0.000)
	Logpcgdp	0.097	(0.427)	0.049	(0.689)	0.100	(0.395)	0.049	(0.651)	0.106	(0.349)

Notes: (***), (**) and (*) refer to 1%, 5% and 10% significance levels, respectively. The values in parentheses refer to *p*-values.

Source: Authors' own calculation

Evaluating the overall results, we conclude that how high/low a country is ranked relative to the other countries in terms of ECI does not have an effect on unemployment. In other words, the decreasing effect of ECI on unemployment is not related to the relative value of the country's ECI level. Moreover, it is noteworthy that there is a dissociation among countries in terms of the examined effect. Thus, the relationship between structural and institutional features and unemployment needs to be considered. Due to the lack of regular data for the country group and the period used in the present study, these data could not be included or empirically examined. However, it can be considered that the available data on these features can provide some insights into the importance of structural and institutional features. Appendix E includes "qualification mismatch index" and "over-qualification index" values. Qualification mismatch increases when workers have educational skills that are higher or lower than what is required for their job. If these workers' education level is higher than what is required for their job, workers are classified as over-qualified (OECD, 2022a). There are no values for China, Indonesia, India or South Korea in Appendix E due to the lack of data availability. However, the existing values shed light on the importance of a well-organized labour market. For instance, Poland, where the ECI level has a significantly decreasing effect on all types of unemployment, has the lowest mismatch index. Brazil, Türkiye and Argentina, whose ECI values also have a significantly decreasing effect on unemployment, have relatively low values of qualification mismatch. Regarding the over-qualification index, Poland has the lowest value again, meaning that workers can match jobs almost equal to their skills. This fact may help create a decreasing effect of ECI on all unemployment types. Briefly, some insight might be inferred from the case of Poland that structural and institutional properties of labour market work as a channel that leads to the decreasing effect of ECI on unemployment.

The results for Asian and African BEM countries, namely China, India, Indonesia, South Korea and South Africa, reveal that economic complexity level, as an indicator of structural transformation, does not decrease unemployment. It is especially noteworthy when China, the second-largest economy in the world, and South Korea, a success story of economic growth since the 1960s, are considered. When considering the power of those countries to shape the future of the world economy, this result highlights the need to consider that the primary aim of those emerging economies is to provide economic growth, not economic development. Since unemployment is both a social and economic problem, structural change must not dissociate from this problem.

Regarding the control variables, it is observed that the inflation variable negatively affects unemployment in Mexico, while it positively affects South Korea and Türkiye. This positive relationship may happen if uncertainty in inflation causes a decrease in investments. The Log(*import*) variable has a negative effect on unemployment in Argentina, Brazil, India, Poland, South Africa and Türkiye. This result confirms that imported goods are used in domestic production. The Log(*pcgdp*) variable affects unemployment negatively in China, India, Indonesia, Mexico and Poland, in line with the theoretical expectation, while it affects South Korea positively.

5. Conclusion and Policy Implications

There are several variables that affect unemployment: trade openness, growth, inflation, exchange rate, investments, institutional structure of countries, physical and human capital, depth of the market, legal infrastructure, etc. All these variables are accepted as *ceteris paribus* under the study constraints. The aim of this study was to reveal how the economic complexity index, which is accepted as an indicator of structural transformation, affects unemployment. Starting from this question, the unemployment situation on the labour market, especially of the gender-disadvantaged segments, was examined. This study also aimed to understand the dynamics behind the link between structural transformation and unemployment by comparing the results for each country. For this purpose, various definitions of unemployment were used and some macroeconomic control variables were included. The effect of economic complexity on unemployment, male-female unemployment, and youth female-youth male unemployment rates in BEM countries between 1998 and 2019 was examined by establishing five separate models. Inflation, imports and GDP per capita were used as the control variables in the model. Institutional indicators related to the labour market were not included due to the lack of data availability. Firstly, cross-sectional dependence was tested for all variables; secondly, a CADF test was used as a second-generation unit root test; and, thirdly, a parameter constancy test was applied to each model and then a panel regression method with random coefficients was applied. According to the empirical results of the study, ECI leads to a decrease in all types of unemployment only in Poland. For Türkiye, Brazil, and Argentina, it can be said that ECI has a significant negative impact on unemployment. If an evaluation is made for Asian countries, namely China, India, Indonesia and South Korea, it can be concluded that ECI does not have a significant effect on unemployment. Again, the empirical results of the study in terms of gender-based assessment are that ECI significantly reduces female unemployment in countries such as Argentina, Poland and Türkiye. In Brazil and Poland, it has a significant effect on male unemployment. An analysis based on both gender and age showed that Poland is the only country where ECI has a significant negative impact on youth unemployment.

Based on the findings, it can be said that the effect of ECI on unemployment is not related to the countries' ranking in terms of ECI values. Additionally, as a general result of the study, it was found that the economic complexity of a country does not have a decisive effect on the unemployment rates of that country. The results obtained are important for understanding the economic complexity and dynamic relationships on the labour market. In this way, it provides an idea of how countries can use it as a policy tool to combat unemployment and highlights the many economic advantages of increasing their levels of complexity. Policy recommendations in accordance with the empirical findings of the study are given below.

Based on the importance of development accompanying structural change in the economy, it should be noted that there is an urgent need for some policies in Asian economies to enhance employment. The empirical results revealed that there is no significant effect of ECI

on unemployment in China, India, Indonesia or South Korea. These countries are included in one of the most important manufacturing hubs, which is also known as "Factory Asia". There is a high potential to support production for global demand in this region. On the other hand, economic growth not accompanied by increasing welfare will bring not only economic but also social problems. The same inference can be made for South Africa and Mexico. In the other countries, namely Argentina, Brazil and Türkiye, there is no significantly decreasing effect of ECI for all types of unemployment. The empirical results for Poland highlight the importance of policies to regulate the labour market. For this reason, the first important implication of the study results is the importance of the harmony between labour supply and demand. Mismatch between labour supply and demand has an increasing effect on unemployment. Therefore, in the case of qualification mismatch in the first policy proposal, the public authority should take into account sectoral demands and facilitate training services to provide personnel with the necessary qualifications in accordance with active labour policies. This approach will have an employment-increasing effect. In conjunction with this recommendation, the second policy recommendation is that labour demand trends should be monitored regularly. The public authority must understand and manage the dynamics of the labour market through employment agencies (private or public) where workers and employers can be matched within an institutional system. Now, international competition and the employment to be created in this direction require production in high-tech sectors. The fact that economic complexity reduces unemployment by creating new jobs depends, of course, on a well-equipped workforce that can be employed in the complex jobs that are created. Structural transformation also reveals itself when old and traditional professions are replaced by knowledge-intensive jobs. The contributions of the process of job creation and the reduction of unemployment are closely related to education of human capital, which is the main element of this process. For this reason, as a third policy proposal, it is necessary to transform the education system in accordance with the qualifications sought in the labour demand of each country. Human capital should have the knowledge to produce complex high-tech products.

Lastly, the impact of economic complexity on labour markets through foreign trade channels also depends on the creation of trade and the diversion effects of trade. Considering that there is a complementary relationship in the production of all products in general, neighbouring countries will be able to support each other in a positive way. Therefore, as a final policy proposal, it is thought that countries will reduce unemployment by adopting a model based on mutual division of labour and specialization in their relations with other countries with which they have intensive foreign trade relationships. Of course, the fact that foreign trade has an employment-enhancing effect is also related to the fact that the goods produced by the countries participating in the trade are in a complementary relationship with each other. For this reason, countries should produce goods that are subject to foreign trade in a complementary relationship.

Appendix

Appendix A: Cross-section dependence test

Variable	CDLM1	CDLM2	LMadj
Logunemp	230.082 (0.000)	18.455 (0.000)	18.217 (0.000)
Logfemale	200.040 (0.000)	15.289 (0.000)	15.050 (0.000)
Logmale	210.672 (0.000)	16.409 (0.000)	16.171 (0.000)
Logfyouth	209.538 (0.000)	16.290 (0.000)	16.052 (0.000)
Logmyouth	188.591 (0.000)	14.082 (0.000)	13.844 (0.000)
ECI	570.999 (0.000)	54.391 (0.000)	54.153 (0.000)
inflation	164.805 (0.000)	11.574 (0.000)	11.336 (0.000)
Logimport	303.564 (0.000)	26.201 (0.000)	25.963 (0.000)
Logpcgdp	812.330 (0.000)	79.830 (0.000)	79.592 (0.000)

Notes: The values in parentheses refer to the probability values of the test statistics.

Source: Authors' own calculation

Appendix B: Bivariate correlation between independent variables

	ECI	Inflation	Logimport	Logpcgdp
ECI	1	–	–	–
Inflation	−0.1902	1	–	–
Logimport	0.0101	0.073	1	–
Logpcgdp	−0.0632	0.0111	−0.0106	1

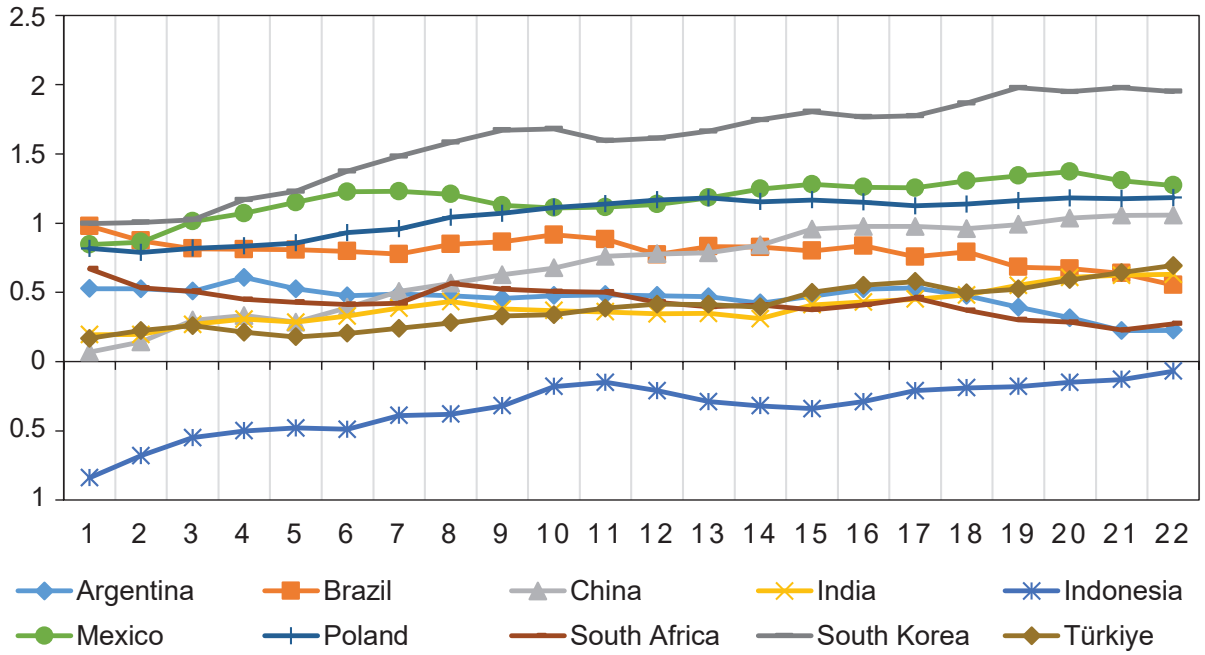
Source: Authors' own calculation

Appendix C: VIF values for dependent variables against multicollinearity

Variable	VIF
ECI	1.04
Inflation	1.04
Logimport	1.01
Logpcgdp	1.00
Mean VIF	1.02

Source: Authors' own calculation

Appendix D : Economic complexity indices of BEM economies (1998–2019)



Source: Authors' own elaboration

Appendix E: Labour market mismatch index

Countries	Qualification mismatch	Over qualification
Argentina	48.5	27.2
Brazil	37.7	28.2
Mexico	50.2	37.7
Poland	22.8	9.2
South Africa	52.2	24.2
Türkiye	43.0	29.1

Source: OECD (2022b)

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