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# Statistical Models to Measure the Impact of Intellectual Property Rights Protection on Foreign Trade in Egypt

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**Abstract** This study aims to estimate the relationship between the Protection of intellectual property rights indices and the foreign trade index in Egypt from 1995 to 2022. The comparison has been made between many models such as the fully modified ordinary least squares (FMOLS) model, dynamic ordinary least squares (DOLS) model, Canonical co-integration regression (CCR) model, and auto-regressive distributed lag (ARDL) model. The results of the study showed that the best model was the ARDL model to increase its explanatory ability. The study also showed that the most important property rights protection indicators affecting the foreign trade index are the number of applications and registrations of brands, the number of patents registered and granted, the number of applications and registrations of industrial designs, and the proportion of expenditure on research and development as a proportion of gross domestic product (GDP). The estimated model also passed all diagnostic tests and showed that there was no auto-correlation and no Heteroskedasticity. In addition, it was found to follow a normal distribution and to be stable.

**Keywords** Foreign trade; Intellectual property rights (IPR) protection; Full modified ordinary least squares (FMOLS) model; Dynamic ordinary least squares (DOLS) model; Canonical co-integration regression (CCR) model; Auto-regressive distributed lag (ARDL) model

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## 1. Introduction

*Innovation* is the main output of scientific research that measures the development and progress of societies. Because of the scarcity of natural productive resources, it has become difficult for countries to rely only on them, and it has also become necessary to invest in the human component because it achieves the competitive advantage and sustainable development of societies. At present, rich nations are measured by its knowledge, intellectuals and creators. One of the most important problems associated with knowledge and scientific progress is the inability to protect ideas, scientific and knowledge production under globalization and ICT. The scientific researches and patents are the most important factors to classify universities or scientific research institutions in the world. In addition, the world's most prestigious business companies usually rank high in the corporate rankings because they have quality research centres. It seeks to attract human competencies and provides material support and legal cover to protect the intellectual production of these competencies by providing greater protection of the intellectual property rights of brands and industrial designs. The Egyptian State has launched the National Intellectual Property Rights Strategy to benefit of the role of intellectual property in achieving development goals in various sectors so that it is consistent with the United Nations Sustainable Development Goals 2030, the World Intellectual Property Organization for Development and Egypt's Vision in the Sustainable Development Strategy in 2030 [28].

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It is clear from the previous that the protection of intellectual property rights plays a major role in promoting scientific research and innovation, especially with rapid technological development in all fields. The companies and individuals also need to increase their research work to access more innovation, development and protection of production from theft. In addition the intellectual property rights protection helps to increase commodity trade that represents in the value of exports and imports of these commodities divided by the value of GDP that lead to increase in sustainable development. So this study interests to know the impact of IPR protection indicators which include patents, trademarks, and industrial designs on the index of foreign trade in Egypt. This study aims to identify and highlight on the concept of intellectual property rights protection. It aims also to compare between the following models : the full modified ordinary least squares (FMOLS) model, auto-regressive distributed lag (ARDL) model, dynamic ordinary least squares (DOLS) model, canonical co-integration regression (CCR) model to build a statistical model to measure the relationship between intellectual property rights protection indicators and the index of foreign trade in Egypt. This study assumes the following hypotheses: (1) There is a statistical significant relationship between the following dependent variable : foreign trade and the following independent variables : the number of patents registered and granted, the number of applications and registrations for brands, the number of applications and registrations for industrial designs in short and long term. (2) There is a statistical non-significant relationship between the foreign trade and the following independent variables: the research and development expenditure ratio as a proportion of gross domestic product, a number of researchers engaged in research and development, foreign direct investment and GDP in the short and long term. (3) The explanatory ability of DOLS model is expected to be higher than the following models: ARDL, CCR, and FMOLS models to measure the impact of IPR protection indicators on the index of foreign trade in Egypt.

## 2. Literature review

Auriol et al.[7]proposed an empirical analysis of the determinants of the adoption of Intellectual Property Rights (IPR) and their impact on innovation in manufacturing. The analysis is conducted with panel data covering 112 countries. First we show that IPR protection is U-shaped with respect to a country's market size and inverse-U-shaped with respect to the aggregated market size of its trade partners. Second, reinforcing IPR protection reduces on-the-frontier and inside-the-frontier innovation in developing countries,without necessarily increasing innovation at the global level. Dussaux et al.[15]evaluated the effect of IPR protection on the two main channels of international low-carbon technology transfer, namely trade in low-carbon capital goods and foreign direct investment by firms owning low-carbon technologies. Our data describe transfer through these channels among 140 countries in eight climate-friendly technology areas between 2006 and 2015. They found that stronger IPR protection in recipient countries increased transfer in six technology areas (solar photovoltaic, solar thermal, wind, heating, lighting, and cleaner vehicles), while the effect is statistically insignificant in the other two (hydro and insulation). The results differ slightly when focusing on the case of non-OECD countries. Stricter IPRs did not have a statistically significant impact on trade in low-carbon capital goods, but they accelerated foreign direct investment in almost all low-carbon technology areas. Igwe and Chris-Sanctus.[18]used the documentary method of data collection and analysis created using content analysis, while time chain research design was adopted. The findings revealed that the United States Government could not adequately demonstrate China's violation of the trade agreement. The study therefore, strongly recommended strict adherence to the provisions of the Agreement on Trade-Related Aspects of Intellectual Property Rights by the parties as established by the World Trade Organization and the World Intellectual Property Organization. Ditimi et al.[12] explored the relationship between trade,intellectual property rights (IPR) and the level of economic development during 1991-2018 in NIGERIA using the auto-regressive distributed lag (ARDL) model. The results also revealed that trade showed a temporary positive impact on the level of economic development, possibly due to instability in the macroeconomic environment and its over dependence on imported goods. Interestingly, foreign investment direct had a positive and significant impact on the country's economic development. The study concluded that both the trade and the intellectual property were unable to influence economic development during the study period because of the weak protection of intellectual property rights and the nature of the country's mono-product. Based on the above, the study recommends that the government provide an enabling environment that will further attract foreign investment and enhance the protection of the country's intellectual property rights and exports. Leming et al.[25] examined the impact of host countries' property rights institutions on foreign direct investment during the period 1996-2012, using Panel Data Analysis, the study found that changes in the quality of property rights in multinational companies have a significant impact on the valuations of multinational companies. Chu et al.[10] developed an open-economy growth model in two intermediate production sectors that use domestic and foreign inputs. They have found that intellectual property rights (IPR) have a positive effect on innovation in the sector that uses domestic inputs but both positive and negative effects on innovation in the sector that uses foreign inputs. They have tested these theoretical results using an empirical analysis of matching samples that combine Chinese provincial IPR database, patent database, industrial enterprises database and customs database of China. Inayatul[19]estimated The relationship between innovation and GDP per capita in Canada, South Korea and Pakistan using time series in the period (1991-2011). The study found a positive impact between technological innovation and the state's economic growth. The study found that factors affecting on innovation are foreign direct investment flows, research and development expenditures, high-tech exports, number of patents for residents, scientific and technical magazine articles, a number of patents for residents and non-residents, spending on research and development. Iryna and Ivelyna[20] studied the impact of innovation through the use of the Internet on human development. This study was applied to the Economic Community of West African States (ECOWAS) which include 15 countries. The study used panel data analysis based on several variables such as the innovation index, the number of internet users, local credit, and students in primary schools between 2004 and 2014. The study found that there was an impact of innovation on human development and economic development in general. Istvan[21]studied the impact of property rights protection and the type of political system on economic growth and took a sample consisting of 128 countries using the multiple regression analysis model. The results showed that there is a positive relationship between property rights and economic growth. Maradana et al.[26] examined the relationship between innovation and GDP per capita. This study applied to 19 European countries in the period (1984-2014). The Co-integration and Granger causality tests were used by six innovation measurement indicators such as a number of patents for residents and non-residents, expenditure on research and development, research and development activities, high-tech exports, and scientific and technical journal articles. The study found a two-way causal directions between innovation and GDP per capita. Quattara and Standaet[29]examined the impact of property rights on income inequality by taking a sample of 190 countries in the period 1995-2012 using the panel dynamics model by the generalized method of moments (GMM), and the X-differencing technique. The results showed the countries that have a high democratic, the protection of property rights from income inequality is reduced. Raizada and Dhillon [38] analyzed the effect of intellectual property rights (IPR) on Indian trade using Johansen's co-integration test, vector error corrected model and granger causality approach. This study used foreign trade, patents, copyrights, trademark for Indian economy from 1997 to 2014 . The empirical result showed that there was a significant long run relationship between Indian trade and export and import of patent related commodities. It means that they were significantly contributing towards Indian trade. The short run vector error correction model (VECM) reveals that Indian Trade respond significantly to re-establish the equilibrium relationship whenever there is any disturbance in the system in long run. The granger causality test showed that there was unidirectional causality running from Indian trade to export and import of patent and trademark related commodities. Andreea et al.[5]analyzed the impact of innovation on the long-term economic growth of the Czech Republic, Hungary and Poland using multiple regression models based on the following independent variables (Number of patents, number of trademarks, research and development expenses, research and development activities, human capital, foreign direct investment) The results found that the number of patents and trademarks, human capital and foreign investment had a positive impact on economic growth, competitiveness and sustainable development. Giorgio and Margherita[17]tried to test the relationship between innovation and economic growth in a number of European countries using a multiple regression model. The study found that technology was the most important tool for increasing a country's economic growth rate. It is clear from previous studies that it focused on examining the relationship between the Global Innovation and Sustainable Development Index and others focused on the relationship between the intellectual property rights protection indicators and both sustainable development and foreign direct investment and income inequality. We rarely find studies that examine the relationship between IPR indicators and Egypt's foreign trade. Before presenting the study's methodology, the concept of intellectual property and its most important indicators are identified. We also rarely find a study that compared between the following models, such as ARDL, FMOLS, DOLS and CCR models, then select the best model for measuring IPR protection indicators on Egypt's foreign trade. The study will show concept of the intellectual property and its most important indicators.

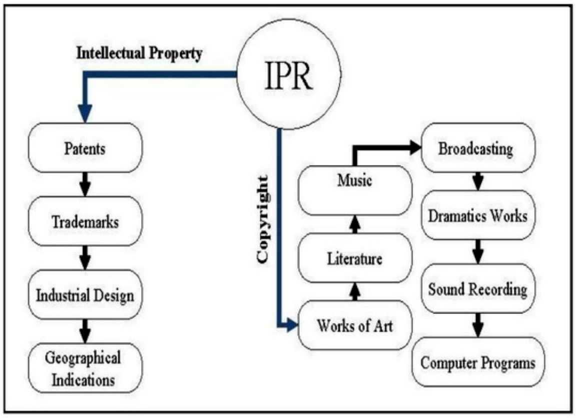


Figure 1. Classification of intellectual property rights (IPR).

**Definition of intellectual property rights:** Intellectual property rights are defined according to the World Organization for the Protection of Intellectual Property (WIPO) as the human product of inventions, artistic creations, and other products of the human mind. It also referred to works of creative thought, literary and artistic works, symbols, names, images and industrial models. The conventions used to divide intellectual property between two main sections:

(1) Intellectual and literary property: It relates to the author's material and moral rights and protection of artistic, literary, audio and visual works, protection of the rights of performers, producers of audio recordings and broadcasting organizations. (2) Industrial property: It means the protection of patents, trademarks, industrial models, drawings and designs, marks of origin or geographical fees, design of integrated topographic circuits, protection of confidential trade information. These two types can be shown in the figure 1.Karina[24]

## 3. Materials and methods

Based on economic theory and previous applied studies, the equation (1) shows the relationship between IPR indicators and foreign trade as follows :

$$FT_t = f\left(TID_t, TP_t, TT_t, ERD_t, RRD_t, FDI_t, GDP_t\right) \tag{1}$$

Where $FT_t$ is The volume of foreign trade, $TP_t$ is the number of total patents registered and granted, $TT_t$ is the total number of applications and registrations for trademarks, $TID_t$ is the total number of applications and registrations for industrial designs, $EDR_t$ is expenditures of research and development as a proportion of GDP, $RRD_t$ is the number of researchers working in research and development, $FDI_t$ is foreign direct investment and $GDP_t$ is gross domestic product:In equation (2) it shows the same variables and adds the random error $\varepsilon_t$ :

$$FT_t = \beta_0 + \beta_1 TID_t + \beta_2 TP_t + \beta_3 TT_t + \beta_4 ERD_t + \beta_5 RRD_t + \beta_6 FDI_t + \beta_7 GDP_t + \varepsilon_t \tag{2}$$

The data sources for current study indicators from 1995 to 2022 have been compiled from the World Intellectual Property Protection Organization (WIPO) [42],World Bank Group (WBG) [41]data, the World Trade Organization (WTO) [43].

### 3.1. Unit root tests

This study used time series data that may be had a problem of instability. So the study used Unit root tests to know if the time series is stable at the level, first difference or second difference. Priyankara [37]. It used also the following tests: Augmented Dickey-Fuller (ADF) test, Dickey and Fuller [11], and the Philips-Perron (PP) test, Phillips and Perron[35].

$$\Delta Z_t = \delta_0 + \delta_1 Z_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta Z_{t-1} + \mu_t \tag{3}$$

$$\Delta Z_t = \delta_0 + \delta_1 t + \delta_2 Z_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta Z_{t-1} + \mu_t \tag{4}$$

The ADF test is conducted when exists a time trend or not in a time series.The equation (3) is used in the case existence of a constant parameter and there is no the time trend, while the equation (4) is the used in the case existence of a constant parameter and a time trend, Agiakloglou and Newbold [3],Cheung and Lai[9], and Dritsakis[14]. ADF test is used for equations (3) and (4) to make sure there is no unit root for $Z_t$. Both "t" and "k" refer to time and the number of lagged periods respectively. $\Delta Z_{t-1}$ indicates to the first difference for the variable with k number of lagged periods, $\mu_t$ is the limit that used to modify autocorrelation errors K, $\alpha_i, \delta_0, \delta_1 \& \delta_2$ are estimated parameters. $H_0$ represents null hypothesis which means that $Z_t$ has unit root. $H_A$ represents the alternative hypothesis which means that $Z_t$ has not unit root and the variable is stable.Dritsakis[14]. We will present in the following ARDL boundary test for co-integration and Johansson and Juselius test.

### 3.2. ARDL bound test for co-integration

This study uses the ARDL which developed by Montenegro [27] to know the relationship between the IPR protection indicators and foreign trade index in Egypt. The ARDL model offers two limits of critical values; The first is when some variables are stable at level I (0), and the other is stable at the first difference I (1). The ARDL model can be applied whether the chains are stable at level I (0) only or I (1) only or when they are together. Many authors have explained the advantages of the ARDL model versus traditional co - integration tests.Alam and Quazi[4]have pointed out that it is the ideal model applicable even with problem of the internal variables in the model. It is also used to explore the relationship with the short and long term Pattichis[31]. Poon[36]showed that the estimated unrestricted error correction model (ECM) is only suitable when the model achieves the classic linear model assumption. There is also a diagnostic test in the ARDL model to confirm whether the estimated error correction model achieves these assumptions as follows:

(1) Apply Lagrange Multiplier test to know if the errors are auto correlated or not.

(2) Apply autoregressive conditional heteroscedasticity (ARCH) test to know if the estimated model is heterogeneous or symmetrical.

(3) Apply Jarque-Bera test to know if the errors follow a normal distribution or not.

(4) Apply Ramsey Reset test for function shape problem. (5) Apply CUSUM and CUSUMSQ tests to know if the estimated model is stable or not during the period. ARDL's unrestricted error correction model is estimated in the following equation Dritsakia and Stiakakis[13], Paul[32] and Poon[36].

$$\begin{aligned}\Delta FT_t = {} & \beta_0 + \sum_{i=0}^{k} \beta_1 \Delta TID_{t-i} + \sum_{i=0}^{k} \beta_2 \Delta TP_{t-i} + \sum_{i=0}^{k} \beta_3 \Delta TT_{t-i} + \sum_{i=0}^{k} \beta_4 \Delta EDR_{t-i} \\ & + \sum_{i=1}^{k} \beta_5 \Delta RRD_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta FDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta GDP_{t-i} + \lambda_1 TID_{t-1} + \lambda_2 TP_{t-1} \\ & + \gamma_3 TT_{t-1} + \lambda_4 ERD_{t-1} + \lambda_5 RRD_{t-1} + \lambda_6 FDI_{t-1} + \lambda_7 GDP_{t-1} + U_t\end{aligned} \tag{5}$$

$\Delta$ is the factor of difference, $t-i$ is the length of lagged period, $U_t$ is a random error. The co-integration of the variables mentioned in the previous equation was tested by following hypotheses, where we find that the null hypothesis is $H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$, and the alternative hypothesis is $H_A : \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq 0$. The null hypothesis of the equation can be tested by calculating F-statistics and comparing it with the critical values of the lower and upper limits Pesaran et.al. [33]. If the F-Statistical is greater than the critical value of the upper bound is at the level of significance $5\%$. So the null hypothesis is rejected, this means that there is a long-term relationship between the variables. If the F-Statistical is less than the critical value of the lower bound, this means no long-term relationship. Finally, if the F-statistical lies between the critical values of the minimum and the critical values of the upper limit, the inference is inconclusive, and we will use the ARDL model, and Johansen and Juselius co-integration test to reconfirm the results obtained from the ARDL model Johansen[22].

### 3.3. *Co-integration tests*

The co-integration between the variables of the model is revealed through the analysis of Johansen and boundary tests, and the equation of the Johansen and Juselius test in the vector auto-regressive (VAR) model can be written as follows:

$$\Delta Z_t = \phi + \Gamma_1 \Delta Z_{t-1} + \ldots\ldots\ldots + \Gamma_{p-1} \Delta Z_{t-p+1} + \Pi Z_{t-1} + \mu_t \tag{6}$$

Where $\phi$ is the vector with rank (Px1) for the constant limit, $\Delta$ is the factor of difference, $Z_t$ is the vector with rank (Px1) for the variables in the model, $\Gamma$ is the matrix of coefficients, $\mu_t$ is the vector with rank (Px1) for the random limit, $\Pi$ represents coefficients matrix with rank (PxP), which shows the long-term relationship between the $Z_t$ variables.Dritsakis[14].

Johansen and Juselius[23]suggested that there are two tests to find the number of co-integration vectors in the VAR model. The first test is the trace test and the null hypothesis $H_0$ which means that the number of equations of co-integration between variables is equal to the rank of the matrix r. The alternative hypothesis $H_A$ means that the number of vectors is greater than the rank of the matrix $r$. The statistic test is calculated from the following equation:

$$\lambda_{\text{trace}} = {}_{-T} \sum_{i=r+1}^{n} \ln\left(1-\lambda_i\right) \tag{7}$$

Where $T$ represents the sample size, and $\lambda$ represents as many relationships as possible. The second test is the Max-Eigen value test, which tests the null hypothesis $H_0$ which means that the number of equations of co-integration between variables is equal to the rank of the matrix $r$. The alternative hypothesis $H_A$ means that the number of vectors is equal $r+1$. The statistic test is calculated from the following equation:

$$\lambda_{\max} = -T\left(1-\lambda_{r+1}\right) \tag{8}$$

The null hypothesis is rejected and the alternative hypothesis is accepted in the two tests if the calculated value is greater than the critical value at level of significant at $5\%$. Once the co-integration relationship has been established, the next step is to estimate the long-term and short-term relationship between the variables.

According to above from equation (9), the error correction model (ECM) to estimate the short-term relationship is formulated as follows:

$$\begin{aligned} \Delta ET_t = \theta_0 &+ \sum_{i=0}^{k} \theta_1 \Delta TID_{t-i} + \sum_{i=0}^{k} \theta_2 \Delta TP_{t-i} + \sum_{i=0}^{k} \theta_3 \Delta TT_{t-i} + \sum_{i=0}^{k} \theta_4 \Delta EDR_{t-i} \\ &+ \sum_{i=1}^{k} \theta_5 \Delta RRD_{t-i} + \sum_{i=1}^{k} \theta_6 \Delta FDI_{t-i} + \sum_{i=1}^{k} \theta_7 \Delta GDP_{t-i} + \varphi ECM_{t-1} + v_t \end{aligned} \tag{9}$$

Where $\theta_0$ is the constant; the short-term coefficients are $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7 \cdot ECM_{1t-1}$ represents the error correction term that explains the speed of adjustment. $v_{1t}$ represents the error term.

This study also uses the following methods FMOLS, CCR, and DOLS to reconfirm the results obtained in the ARDL model and to examine the robustness of this model.

This analysis re-estimates the model (3) using the FMOLS method which developed by Phillips and Hansen[34],the CCR method that introduced by Park[30],and the DOLS method that developed by Stock and Watson[40] to obtain robust estimates.

### 3.4. Fully modified least squares (FMOLS) estimators

The FMOLS method adopts a semi-parametric approach to estimate the parameters in the long term.Adom et al.[1] and Fereidouni et al.[16].

This method gives consistent parameters when the sample size is small and it can overcome the problems of homogeneity, auto-correlation, the bias of omitted variable, and the measurement errors. It allows also heterogeneity parameters in the long term. Agbola [2], Bashier and Siam [8],and Fereidouni et al.[16].

The FMOLS method also estimates a single co-integration relationship that has the stable variables at first difference. Bashier and Siam [8].This model focuses also on the transformation of both data and parameters Park[30].

Amarawickrama and Hunt[6] showed that the FMOLS method makes the appropriate correction of inference problems of co-integration. They showed also that the FMOLS estimator can be obtained as follows:

$$\widehat{O}_{FMOLS} = \left(\sum_{t=1}^{T} Z_t Z_t'\right)^{-1} \left(\sum_{t=1}^{T} Z_t Y_t^+ - T \begin{bmatrix} \lambda_{12'}^+ \\ O \end{bmatrix}\right) \tag{10}$$

It is clear from equation (10) that the bounds $\left(Y_t^+ \& \lambda_{12'}^+\right)$ is used to correct homogeneity and auto-correlation for errors. The FMOLS estimator is unbiased and it had an asymptotic distribution for normal distribution. It used also Wald tests using Chi-Square statistic. Adom et al.[1]

### 3.5. Canonical co-integration regression (CCR) model

Park [30] presented another approach which depends on CCR estimator. This approach can also be used to test co-integration vectors in the model with an integrated operation of rank I (1).

This model is like the FMOLS model. However, the difference between both FMOLS and CCR, that CCR focused on data transformation only but FMOLS focused on transformation of both data and parameters. Adom et al.[1] and Park [30]. Moreover, the CCR is represented a single equation of regression. It can also be applied multivariate regression without modification and loss of efficiency Park[30].

In the equation (11) the CCR estimator is obtained as follows. Adom et al.[1].

$$\widehat{O}_{CCR} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*1}\right)^{-1} \sum_{t=1}^{T} Z_t^* Y_t^* \tag{11}$$

### 3.6. Dynamic ordinary least squares (DOLS) model

The DOLS model is one of the most powerful methods due to its performance in small-sized samples, where it is used to estimate the long-term parallel relationship of a system that includes co-integrated variables with different degrees. This method was developed by Stock and Watson[40]and is based on the values of lags and leads for $X_t$.The estimator of the dynamic ordinary least squares can also be written as follows:

$$\tilde{O}_{DOLS} = \left(\sum_{t=k+1}^{T-K} \tilde{Z}_t \tilde{Z}_t'\right)^{-1} \left(\sum_{t=k+1}^{T-k} \tilde{Z}_t \tilde{Y}_t^{-}\right) \tag{12}$$

Where $\tilde{Z}_t \& \tilde{Y}_t$ are the regression errors for $Z_t \& Y_t$.

## 4. Results and Discussion

The research measures the impact IPR indicators on the foreign trade index using the following models : fully modified ordinary least Squares (FMOLS) model, dynamic ordinary least squares (DOLS) model, canonical co-integration regression (CCR) model and auto-regressive distributed lagged (ARDL) model to estimate long term relationships, also through the error correction model (ECM) will estimate short-term relationships. Then we will select the best model for measuring the impact of IPR protection indicators on foreign trade in Egypt by using statistical software E-views v.12.This research shows the steps of building the statistical model from 1995 to 2022. It can be applied on time series that stable at level I (0) or stable on the first difference I (1) or mix of both. The only condition for applying this test is that the time series is not stable with the second difference I(2).The ARDL model is an important model to estimate the integration of variables for short and long term. It can also be seen whether there is an integrated balance between the dependent variables and the independent variables in the long and short term.

### *4.1. Descriptive statistics*

The table 1 shows the most volatility variables such as $TID_t, TT_t, TP_t$ and $RRD_t$. As well as the Jarque - Bera test shows that $FT_t, TP_t, TT_t, TID_t, ERD_t$ and $GDP_t$ are variables that follow the normal distribution, but $RRD_t$, and $FDI_t$ are variables that do not follow the normal distribution. The skewness coefficient shows that all variables deviates to the right side, but the variable $TP_t$ deviates to the left side.

### *4.2. Unit root tests*

The table 2 shows the results of ADF and PP tests at level and the first difference with the existence of constant or constant and trend condition.

Table 1: Descriptive statistics

| Variable | FT | TID | TP | TT | ERD | RRD | FDI | GDP |
|---|---|---|---|---|---|---|---|---|
| Mean | 30.2 | 46010 | 2261 | 27574 | 0.5 | 1420 | 2.4 | 4.4 |
| Median | 29.4 | 3357 | 2450 | 27313 | 0.4 | 832 | 1.5 | 4.4 |
| Maximum | 45.8 | 8239 | 2945 | 57236 | 1.3 | 6015 | 9.3 | 7.2 |
| Minimum | 18.8 | 2615 | 1019 | 13445 | 0.2 | 433 | -0.2 | 1.8 |
| Std. Dev. | 8.0 | 2112 | 515 | 11048 | 0.3 | 1382 | 2.4 | 1.6 |
| Skewness | 0.3 | 0.7 | -0.6 | 1.0 | 0.9 | 1.9 | 1.8 | 0.0 |
| Kurtosis | 1.8 | 1.8 | 2.5 | 3.7 | 3.0 | 6.0 | 5.3 | 2.1 |
| Jarque-Bera | 2.04 | 4.24 | 2.14 | 5.48 | 4.13 | 28.37 | 20.63 | 0.94 |
| Probability | 0.36 | 0.12 | 0.34 | 0.06 | 0.13 | 0.00 | 0.00 | 0.62 |
| Sum | 845.09 | 129063 | 63302 | 772074 | 13.24 | 39772 | 67.04 | 123.61 |
| Sum Sq. Dev. | 1716.11 | $12E + 7$ | 7162989 | $33E + 8$ | 3 | 51526231 | 154 | 65 |
| Observations | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |

Table 2: Unit root tests

| | level | | | | 1st diff. | | | |
|---|---|---|---|---|---|---|---|---|
| | Con. | | Con.and Trend | | Con. | | Con.and Trend | |
| ADF | t-Stat. | Prob. | t-Stat. | Prob. | t-Stat. | Prob. | t-Stat. | Prob. |
| FT | -1.50 | 0.52 | -1.17 | 0.90 | -4.01 | 0.00* | -4.10 | 0.02** |
| TID | -1.39 | 0.57 | -1.87 | 0.64 | -4.96 | 0.00* | -6.97 | 0.00* |
| TP | -1.89 | 0.33 | -2.63 | 0.27 | -4.90 | 0.00* | -4.87 | 0.00* |
| TT | 1.61 | 1.00 | -1.58 | 0.77 | -3.60 | 0.01** | -4.05 | 0.02** |
| ERD | 3.08 | 1.00 | 0.03 | 0.99 | -0.90 | 0.77 | -5.59 | 0.00* |
| RRD | -0.83 | 0.79 | -2.71 | 0.24 | -6.01 | 0.00* | -3.28 | 0.09 |
| FDI | -3.12 | 0.04** | -3.01 | 0.15 | -3.01 | 0.05** | -3.00 | 0.15 |
| GDP | -3.38 | 0.02* | -4.28 | 0.01** | -4.72 | 0.00* | -4.65 | 0.01* |
| PP | t-Stat. | Prob. | t-Stat. | Prob. | t-Stat. | Prob. | t-Stat. | Prob. |
| FT | -1.50 | 0.52 | -1.17 | 0.90 | -3.94 | 0.01* | -3.98 | 0.02** |
| TID | -1.40 | 0.57 | -2.07 | 0.54 | -4.96 | 0.00* | -4.92 | 0.00* |
| TP | -1.83 | 0.36 | -2.77 | 0.22 | -5.22 | 0.00* | -5.18 | 0.00* |
| TT | 1.67 | 1.00 | -0.86 | 0.95 | -3.53 | 0.02** | -3.94 | 0.03** |
| ERD | 3.20 | 1.00 | 0.05 | 0.99 | -4.04 | 0.00* | -5.58 | 0.00* |
| RRD | -9.28 | 0.00* | -5.97 | 0.00* | -6.61 | 0.00* | -10.46 | 0.00* |
| FDI | -2.11 | 0.24 | -2.03 | 0.56 | -3.10 | 0.04** | -3.09 | 0.13 |
| GDP | -2.35 | 0.16 | -2.60 | 0.28 | -4.72 | 0.00* | -4.65 | 0.01* |

Note: * and ** indicate significant at 1% and 5% level.

It is clear from the previous table that the following variables are $FT_t, TP_t, TT_t, TID_t$ and $RRD_t$ were stabilized at the first difference but $ERD_t, FDI_t$ and $GDP_t$ were stabilized at the level whether with the constant or with the constant and trend. This means that the ARDL methodology can be used.

### *4.3. ARDL co-integration tests*

The Johansen analysis and Bounds tests will be used to discover the co-integration relationships between the model variables.

*4.3.1.* ***Johansen co-integration analysis*** . It is clear from table 3 that there are eight co-integration relationships according to the Trace and the Max-Eigen value tests in foreign trade model at level of significant $5\%$. It is clear from the previous table that there are the long-term equilibrium relationships between variables.

Table 3: Johansen co-integration analysis

| Series: FT TID TP TT RRD ERD FDI GDP | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hypothesis | | Trace | 0.05 | | Max-Eiger | 0.05 | |
| $H_0$ | $H_A$ | Statistic | ritical Va | e Prob.** | Statistic | Critical Va | Prob.** |
| $CV = 0$ | $CV \geq 1$ | 214.33 | 52.36 | $0.00*$ | 526.97 | 159.53 | $0.00*$ |
| $CV \leq 1$ | $CV \geq 2$ | 112.50 | 46.23 | $0.00*$ | 312.64 | 125.62 | $0.00*$ |
| $CV \leq 2$ | $CV \geq 3$ | 68.44 | 40.08 | $0.00*$ | 200.14 | 95.75 | $0.00*$ |
| $CV \leq 3$ | $CV \geq 4$ | 53.26 | 33.88 | $0.00*$ | 131.70 | 69.82 | $0.00*$ |
| $CV \leq 4$ | $CV \geq 5$ | 30.31 | 27.58 | $0.02*$ | 78.44 | 47.86 | $0.00*$ |
| $CV \leq 5$ | $CV \geq 6$ | 25.29 | 21.13 | $0.01*$ | 48.13 | 29.80 | $0.00*$ |
| $CV \geq 6$ | $CV \geq 7$ | 16.92 | 14.26 | $0.02*$ | 22.84 | 15.49 | $0.00*$ |
| $CV \geq 7$ | $CV \geq 8$ | 5.92 | 3.84 | $0.02*$ | 5.92 | 3.84 | $0.02*$ |

* Indicates that rejection of $H_0$ at 5% level.**MacKinnon-Haug-Michelis (1999) p-values.

*4.3.2.* ***Bounds test*** .The bounds test is based on the F-test. The results of this test are more accurate compared to the traditional tests Shahbaz et al.[39].The table 4 shows the results of the bounds test which shows that the value of F-calculated greater than F-tabulated at $10\%$ level. So, it will reject $H_0$ and accept $H_1$, which means that there are co-integration relationships between variables in the long term.

Table 4: ARDL Bounds test for cointegration

| Series: FT TID TP TT RRD ERD FDI GDP | | | | |
|---|---|---|---|---|
| Test Statistic | | | | |
| F- statistic | | Critical Value Bounds Sign | I0 Bound | I1 Bound |
| Value | 2.253 | $10\%$ | 2.03 | 3.13 |
| K | 7 | $5\%$ | 2.32 | 3.5 |
| | | $2.50\%$ | 2.6 | 3.84 |
| | $1\%$ | 2.96 | 4.26 | |

### *4.4. ARDL model estimates*

The table 5 shows that in the short term there is a significant relationship between $FT_t$ and the following variables ($TT_t, TID_t$ and $ERD_t$). We note also that in the long term there is a significant relationship between $FT_t$ and the following variables ($TT_t, TP_t \cdot TID_t$ and $ERD_t$), in addition to the significance of the constant.

Table 5: ARDL long-run and short-run relationship

| ARDL$(1,0,0,0,1,0,0,0)$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Long-Run | | | Short-Run | | |
| Variable | Coeff. | t-Stat. | Prob. | Variable | Coeff. | t-Stat. | Prob. |
| TID | -0.005 | -5.644 | 0.000 | D(TID) | -0.005 | -3.806 | 0.001 |
| TP | 0.005 | 2.169 | 0.045 | D(TP) | 0.005 | 1.976 | 0.065 |
| TT | 0.001 | 3.063 | 0.007 | D(TT) | 0.001 | 2.513 | 0.022 |
| RRD | 0.000 | -0.183 | 0.857 | D(RRD) | -0.004 | -1.600 | 0.128 |
| ERD | -49.914 | -4.569 | 0.000 | D(ERD) | -52.16 | -3.415 | 0.003 |
| FDI | -0.192 | -0.286 | 0.778 | D(FDI) | -0.200 | -0.283 | 0.781 |
| GDP | 0.493 | 0.654 | 0.522 | D(GDP) | 0.516 | 0.638 | 0.532 |
| C | 38.873 | 7.144 | 0.000 | CointEq(-1) | -1.045 | -5.410 | 0.000 |
| R-squared | 0.882 | | | | | | |
| Adj.R-squared | 0.820 | | | | | | |
| F-statistic | 14.16 | | | | | | |
| Prob(F-statistic) | 0.000 | | | | | | |
| Durbin-Watson stat | 2.280 | | | | | | |

It is clear from table 5 that the coefficient of error correction in the ARDL short term model is significant at the $5\%$ level and has a negative signal. Its value indicates that the speed of adjustment for any imbalances or shocks occurs in foreign trade value is $104.5\%$ per year, which means the speed of adjustment of any imbalance and return it to the stability.

The results of F-test showed the significance of the foreign trade model. Also, the adjusted R-squared coefficient was $82\%$, which means that the model is good because it has a high explanatory ability. In addition, it was found that Durbin-Watson statistic reached to 2.280. That means there is not an auto-correlation between errors.

### *4.5. Robustness check analysis*

The robustness check analysis will be used the FMOLS, CCR, and DOLS models to confirm the results which obtained in the ARDL model. It also is important to test the sensitivity of the parameters which obtained from

ARDL model. This analysis reassesses the model using the FMOLS method that developed by Phillips [34],as well as it is used the CCR method which introduced by Park [30], and the DOLS method which introduced by Stock and Watson[40] to obtain robustness estimates.

Table 6. Robustness check analysis

| Model | FMOLS | | DOLS | | CCR | | ARDL | |
|---|---|---|---|---|---|---|---|---|
| Variable | Coeff. | Prob. | Coeff. | Prob. | Coeff. | Prob. | Coeff. | Prob |
| TID | -0.005 | 0.000 | -0.004 | 0.000 | -0.004 | 0.000 | -0.005 | 0.000 |
| TP | 0.005 | 0.015 | 0.004 | 0.013 | 0.005 | 0.048 | 0.005 | 0.045 |
| TT | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.013 | 0.001 | 0.007 |
| RRD | 0.001 | 0.303 | 0.001 | 0.309 | 0.001 | 0.216 | 0.000 | 0.857 |
| ERD | -47.516 | 0.000 | -47.118 | 0.000 | -48.055 | 0.000 | -49.914 | 0.000 |
| FDI | 0.036 | 0.947 | 0.022 | 0.961 | 0.001 | 0.999 | -0.192 | 0.778 |
| GDP | 0.468 | 0.446 | 0.415 | 0.425 | 0.500 | 0.475 | 0.493 | 0.522 |
| C | 38.322 | 0.000 | 39.551 | 0.000 | 37.512 | 0.000 | 38.873 | 0.000 |
| R-squared | 0.853 | | 0.858 | | 0.853 | | 0.882 | |
| Adj. R-squ. | 0.799 | | 0.808 | | 0.799 | | 0.820 | |

The table 6 showed that the ARDL model results are consistent with the results of the following models (FMOLS, CCR, and DOLS) in the long term, where the following variables $TT_t, TID_t$ and $ERD_t$ were significant in the long term . It is clear also from this analysis that these variables are most influential on the value of foreign trade. As well as the ARDL model was having a higher explanatory ability than the FMOLS, CCR, and DOLS models.

### *4.6. Diagnostic and stability tests of the model*

The table 6 indicates that the estimated model is identical and does not suffer from the problem of auto-correlation and Heteroskedasticity. In addition, the residuals follow a normal distribution, and the function's shape has been correctly formulated.

Table 7: Diagnostic tests

| Series: FT TID TP TT RRD ERD FDI GDP | | |
|---|---|---|
| Test | F-Statistic | Probability |
| Breusch-Godfrey Serial Correlation LM Test | 1.884 | 0.186 |
| Normality- Jarque-Bera | 0.740 | 0.691 |
| Heteroskedasticity Test: Breusch-Pagan-Godfrey | 2.434 | 0.055 |
| Ramsey Reset Test | 0.177 | 0.680 |

The CUSUM and CUSUMSQ tests are used to ensure that there are no structural changes in the data of study. Many studies have shown that these tests are often accompanied with the ARDL methodology. The structural stability of the estimated parameters are achieved if the graph of (CUSUM) and (CUSUMSQ) statistic falls within critical boundaries at the 5% level according to the ARDL model.

The Figures (2) and (3) were shown that the estimated parameters of the correct model used are structurally stable over the study period 16, because the graph of the (CUCUM) and (CUSUMSQ) statistic was within the critical area at the 5% significance level.

## 5. Conclusion

This study aimed to measure the impact of IPR protection and foreign investment and GDP indicators on foreign trade during the period 1995-2022 in Egypt. The study used the ARDL model to estimate the short-term and long-term relationship, and the durability inspection was performed using the following models FMOLS, DOLS and

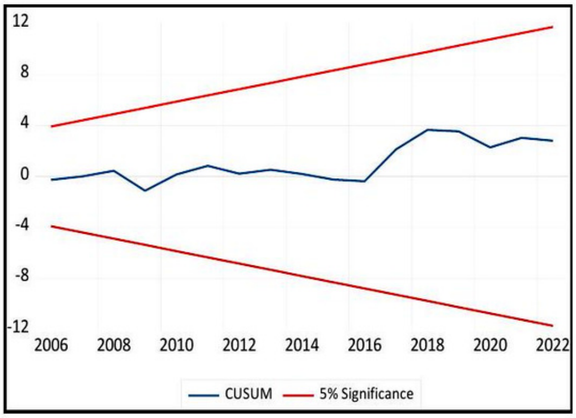


Figure 2. Cumulative sum (CUSUM) of recursive residuals.

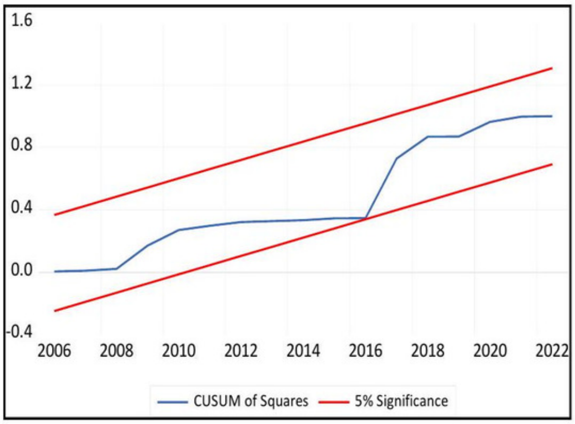


Figure 3. Cumulative sum squares (CUSUMSQ) of recursive residuals.

CCR. The ADF and PP unit root tests showed that time series of study variables are stable. The boundary test for co-integration and the Johansen test also showed the existence of co-integration relationships between variables in the model. The study found that a significant impact between the value of foreign trade and the total number of patents registered and granted, the total number of applications and trademark registrations, and the total number of applications and registrations for industrial designs in the short and long term. So the government must interest intellectual property rights protection, which will lead to more innovations by thinkers and scientists, and this is reflected positively in industrial development in particular and sustainable development in general.

There was a significant relationship between the volume of foreign trade and the proportion of research and development researchers expenditure as a proportion of GDP in the short and long term. This meant increasing the volume of scientific research expenditure will achieve a more patents, registered industrial designs, registered trademarks and a non-significant relationship between the volume of foreign trade and the number of research and development researchers in the short term.

There found also a non-significant relationship between the value of foreign trade and foreign direct investment, GDP and the number of working researchers in research and development in the short and long term, and this may be due to an indirect effect between the value of foreign trade and these variables. So this study recommends to increase a foreign direct investment because it has become necessary to create more productive projects that will lead to increase in GDP and exports, as well as will reduce imports, the trade balance deficit and external debts.

The ARDL model achieved an explanatory ability higher than other models. The results showed that the error correction model (ECM) was negative and significant of the short term.

The estimated model also passed all the diagnostic tests showing that there is not auto-correlation between the residuals and there is no problem of Heteroskedasticity and it follows normal distribution.

The researcher recommends the need to support scientific research, encourage the innovation and protect the IPR in Egypt to find solutions to problems, develop products and meet society's needs in the food, agriculture, industry, technology, health, water, energy and environment and all fields.

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