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# *Exporting Through Complexity: The Indirect Influence of Higher Education on Export Intensity*

**Shenghua Zou**

*The University of Warwick, Coventry, UK*
*sherward.zou@outlook.com*

***Abstract:*** This study examines the socioeconomic determinants of trade performance, with a particular focus on tertiary education, export structure, export intensity, and GDP. The research intention is to figure out whether a country's advantage in higher education translates into stronger export outcomes through a mediating mechanism, and to what extent this effect is observed. To address this question, this research employs mediation analysis using the causal steps regression approach, and the results are reviewed with robustness test using the bootstrap method. Research data come from public open databases. The empirical findings suggest that tertiary education serves as a significant secondary drive of exports. Notably, a substantial portion of this influence operates indirectly and primarily through enhancing the complexity of the export structure. These results imply that the diversity and specialization of university programs underpin the educational edge in export performance, highlighting the critical role of human capital composition in shaping a nation's comparative advantage in international trade.

***Keywords:*** Mediation analysis, Export intensity, Export complexity, Tertiary education.

## 1. Introduction

Despite the regional conflicts and geographical politics, peace and development remain the primary theme of this era [1]. With the irrevocable trend of globalization, international trade has been and will still have been a significant constituent for domestic production. Extensive studies have shown that education imposes a positive influence on exports. Nevertheless, limited studies try to explain through what exact channel does education influence exports. This research focuses on the revelation of the mediation effect of education on exports if there is any.

Export has been an indispensable part in the constitution of an economy, like in one popular method of GDP calculation comprises consumption, investment, government purchases and net exports [2]. And in some Asian countries, for example China, Korea, and Singapore, export has once become one of the most powerful drives for their economies [3]. Export-Led Growth theory has also validated the positive correlation, with the data of 11 countries', between exports and GDP [4].

This correlation can be roughly quantified. The World Bank Report 2020 mentioned every 1% increase in exports can bring about a 0.7% increase in GDP [5]. This report also declared this interaction is more distinctive in developing countries. Similar finding is also found by IMF. IMF Annual Report 2022 on developing countries over 1970 – 2015, it is declared that an increase of

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10% in the proportion of exports to GDP will lead to an average increase from 0.4% to 0.6% in the annual GDP growth rate [6].

Previous research has demonstrated a strong correlation between export intensity and a country's economic development. In other words, it can be highly pragmatic to promote a country's economic development by expanding its export intensity.

When scientists try to study the fundamental drives that influence exports, education is one factor that cannot be overlooked [7]. Multiple theories have proved the impact of education to an economy's development. New Growth Theory indicates educational accumulation is an endogenous driver of long-term economic growth, and human capital can generate externalities that stimulate growth across the entire economic sector [8]. In Skill-based Trade Theory similar ideas were also mentioned but from more of an export structure perspective. Comparative advantages among countries have been less influenced by resource endowments, but increasingly by human capital and skill composition. Highly skilled labor has become a key factor in shaping the structure of exports, particularly in knowledge-intensive industries [9]. Based on these studies, it is clear that education and exports are closely interlinked.

## 2. Literature review

As education and exports are both significant to economic development, many scholars have done their research to supplement the theoretical framework. Here are a few classical theories about the internal mechanism among education, exports, and GDP.

### 2.1. Relation between exports and GDP

Export-Led Growth (ELG) is one unavoidable theory talking about relation between exports and economic growth. The Export-Led Growth (ELG) theory posits that export expansion is a primary driver of economic growth, particularly for developing and emerging economies. Rooted in classical trade theory and gaining prominence in the 1970s and 1980s, ELG suggests that outward-oriented trade policies enhance economic performance by encouraging specialization, achieving economies of scale, and improving resource allocation efficiency [10]. Through export expansion, countries can gain access to larger international markets, attract foreign investment, increase foreign exchange earnings, and stimulate productivity growth.

Hossain formalized this view by demonstrating that the export sector often exhibits higher productivity than the non-export sector and generates positive externalities that spill over into the broader economy [11]. Empirical studies have found significant correlations between export growth and GDP growth in export-oriented countries such as South Korea, Taiwan, and Singapore [12]. Furthermore, increased export activity can stimulate innovation, improve labor skills, and promote structural transformation in domestic industries.

In this context, the ELG framework provides a useful lens to explore how various factors—such as education and human capital can influence a country's export capacity, and in turn, economic development. It is natural to think developed countries which excel in education and knowledge accumulation will take over the majority of the global exports and dominate the trade. This intuitive concept is proved incorrect by Comparative Advantage Theory.

The theory of comparative advantage, first brought by David Ricardo in 1817, remains one of the foundational concepts in international trade theory. It asserts that countries should specialize in the production and export of goods and services in which they have a relative efficiency advantage, even if one country is more efficient in producing all goods. By focusing on comparative instead of

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absolute advantages, countries can trade to mutual benefit, leading to increased total output, resource efficiency, and economic welfare. Comparative Advantage Theory states that countries benefit by specializing in and exporting goods they can produce relatively more efficiently than others, thereby maximizing global output and mutual economic gains through trade.

Over time, the theory has been expanded and refined. Modern interpretations link comparative advantage with factors such as labor productivity, technology, and institutional quality. In dynamic trade models, comparative advantage evolves with human capital accumulation, innovation, and policy choices. Export activity, in this context, reflects a country's underlying comparative strengths and contributes to growth through reallocation of resources to higher-productivity sectors.

Empirical studies have demonstrated that export specialization based on comparative advantage is associated with faster GDP growth, improved employment structures, and higher total factor productivity. Therefore, this theory provides a strong foundation for examining how education and human capital can shape a country's export structure and trade competitiveness, ultimately influencing long-term economic growth.

## 2.2. Relation between education and exports

The relation between education and exports is given equal attention and there are classic theories have revealed the causal logic between them.

Human Capital Theory posits that individuals' education, skills, and health are forms of capital that enhance their productivity and, in turn, contribute to economic growth. Originally developed by economists such as Theodore Schultz and Gary Becker in the 1960s, the theory emphasizes that investments in human capital—particularly through formal education and training—lead to higher earnings for individuals and greater efficiency for economies. Education improves workers' cognitive abilities, adaptability, and innovative capacity, which ultimately boosts firm productivity and national competitiveness.

From a macroeconomic perspective, countries with higher levels of human capital are more likely to experience sustained economic growth, structural transformation, and successful integration into global markets. In the context of international trade, human capital plays a critical role in enabling economies to move up the value chain, produce more sophisticated export goods, and absorb foreign technologies through learning and innovation.

Therefore, Human Capital Theory provides a conceptual basis for understanding how education influences export performance. In particular, it supports the hypothesis that improved education leads to a more skilled labor force, which enhances a country's comparative advantage and export capacity, ultimately contributing to long-term economic development.

New Growth Theory also asserts education can improve exports, and ultimately, boost the economy. However, there are a few different distinctions like the mechanism through which education can stimulate exports. While Human Capital Theory emphasizes how education improves individual productivity and labor efficiency—thereby enhancing export capacity, New Growth Theory extends this view by focusing on how education fosters innovation, knowledge accumulation, and technology diffusion, which are critical for sustaining long-term export competitiveness and economic growth in an open economy [13].

## 2.3. Research gaps

The current studies have concentrated on the relations among education, exports, and economic development. There are different theories argues that education can impose an effect through

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different channels, such as through uplifting individual productivity and labor efficiency, which is a complete economic channel; and through fostering innovation and ultimately, changing the export structure.

However, there is still a lack in quantified methods and proof of how education can affect exports. In other words, the mediation analysis about through what channel education affects exports remains blank. The purpose of this paper, is to provide an insight on how significant education affects exports through changing an economy's export structure via a quantified method.

### 2.4. Research contribution

This study has not only been a supplement to the current theories but also provided insights into practice. Traditional international trade theories primarily focus on resource endowments and comparative advantages, with education often simplified as labor quantity [14]. This study expands the theoretical scope of education's impact on foreign trade by introducing the human capital mechanism, revealing how education quality and skill enhancement indirectly promote exports. This article aims to fill in the blank by concentrating on one mediator, export complexity, to understand how this mediator bridge tertiary education and exports.

Directly managing exports does not seem practicable for there are quite a number of variables jointly influencing exports. Trade and exports are affected by both domestic and foreign factors that cannot be easily managed. In contrast, education is a more controllable factor which can be drastically prioritized by domestic governments. By thorough understanding how education influences exports through changing the export structure, it can be more practical for policy makers to drive exports with the education leverage.

## 3. Methodology and model

In order to decompose the interrelation between tertiary education and export performance, a mediation analysis is necessary. The core idea of carrying out mediation analysis for consecutive variables is to utilize linear regression. Comparing different coefficients in the linear regression models can provide the insights on how close the relations are to each other. For consecutive variables, the linear regression part is the same. There is only a minor difference lying in the interpretation of regression model coefficients when adopting different approaches, e.g. Causal Steps Regression and Bootstrap method.

### 3.1. Variable selection

As for the variables for the research, the main steps of this research include checking the total effect of $X$ on $Y$, using casual steps regression, Baron and Kenny approach to perform mediation analysis, and a robustness test with Bootstrap method in the end. As for the variables in this research, I choose the tertiary enrollment rate as the independent variable to reflect education level, and the export intensity as the dependent variable to represent export performance. These two variables are gathered from ourworldindata.org, and gapminder.org. As the mediation channel we suppose in this article is the export structure, therefore, we decide to use ECI, Export complexity index, as the mediator variable. ECI is invented and maintained by Havard and MIT, which is published on an independent website. All variables cover a timeframe of 25 years from 1998 to 2023, from 119 countries over the world. Overall, the model comprises tertiary education rate as the

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independent variable, export intensity as dependent variable, and the export complexity index as the mediator.

### 3.2. Mediation analysis modeling

The nature of using linear regression to perform mediation analysis is about measuring the correlation between different variables by repetitive usage of linear regression. The overall steps can be concluded in the following equations followed by explanation on each.

$$Y = cX + \varepsilon_1 \tag{1}$$

$$M = aX + \varepsilon_2 \tag{2}$$

$$Y = c'X + bM + \varepsilon_3 \tag{3}$$

For the letters in the equations above, $X$ stands for the independent variable; $Y$ is the ultimate dependent variable influenced by other variables; $M$ represents a potential mediator as a result of $X$ and also an influential factor to $Y$; $c$ is the total effect of $X$ to $Y$ regardless of any mediators; $a$ is the effect of $X$ on $M$ in a mediation analysis model; and $b$ means the effect of $M$ to $Y$, in which context $M$ is the result of $X$ and contribute to $Y$ equally as $X$; $c'$ is the direct effect of $X$ to $Y$, not through $M$, the mediator; $\varepsilon$ shows the error term caused by randomicity.

As for interpretation of Casual steps regression, we will combine all the previous regression results. In equation (1), the first thing is to check if the coefficient $c$ is significant. If $c$ does not prove to be significant enough, the conclusion will simply turn out to be there is no influence of $X$ on $Y$. Thus, the mediation analysis is justifiably brought to an end. If the coefficient in equation (1) proves to be significant, the conclusion would be the opposite, indicating a strong influence of $X$ on $Y$, In which case, the mediation effect estimation goes on.

Given the coefficient c is significant, the next step is about looking into the coefficients a and b in equation (2). Different combinations of coefficients a and b, in this approach, suggest 2 scenarios. One scenario happens when both coefficients turn out to be significant. In which case, the estimation turns to focusing on the coefficient c'. And when look at coefficient c' for its statistical significance, the overall conclusion will be either the mediation effect is realized by full mediation through the mediator variable, or the mediation effect is only partial mediation. The other scenario happens when both shows to be insignificant, in which case a Sobel test is needed to determine the validity of mediation effect.

### 3.3. Robustness test

Robustness check is comprehensively used in mediation analysis to strengthen the conclusion by eliminating misled conclusion due to sample distribution and variable selection. This session will talk about the necessity and practical steps of robustness checks.

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### 3.3.1. The underlying logic of robustness test

The conclusion drawn solely by the Causal Steps Regression method is not reliable all the time. There are multiple advantages explain why a robustness test is necessary: avoiding wrong conclusion drawn due to assumptive data distribution, reinforced conclusion by various methods, quantifying potential bias influence due to unmeasured variables, and strengthened result by placing with different variables or practicing with alternative model specifications (e.g., adding control variables or applying nonlinear models).

For this article in particular, the causal steps regression method proposed by Baron and Kenny does not directly test the statistical significance of the indirect effect i.e., the product of path coefficients [15]. Since this product term typically violates the normality assumption, the commonly used Sobel test may lack statistical power, especially in small samples or when data are skewed. To address this limitation and enhance the robustness of the mediation analysis, this study applies the non-parametric Bootstrap method to estimate confidence intervals for the indirect effect. The Bootstrap approach does not rely on distributional assumptions and is widely recognized as one of the most reliable and powerful methods for testing mediation effects in empirical research.

### 3.3.2. Robustness test method selection

To assess the robustness of the mediation effect, we employed a nonparametric bootstrap approach using the mediate function from the R mediation package. Specifically, we first estimated the mediator model (predicting the mediator from the independent variable) and the outcome model (predicting the dependent variable from both the independent variable and the mediator). We then conducted causal mediation analysis with 5,000 bootstrap simulations to obtain robust estimates of the average causal mediation effect (ACME), average direct effect (ADE), total effect, and the proportion mediated. The bootstrap method provides percentile-based confidence intervals that are less sensitive to violations of normality and small-sample biases, offering a more reliable inference than traditional methods such as the Sobel test. The consistency and statistical significance of the ACME across bootstrap samples confirm the robustness of the identified mediation effect

## 4. Results

This chapter covers the results of the whole mediation analysis, from the total effect model, to mediation model, and to direct effect model. The regression results of each model are put in separate sessions respectively.

### 4.1. Linear regression results

The purpose of this total effect validation as mentioned before is about to prove there exists a clear influence from X to Y. This step lays the theoretical foundation for further steps of a mediation analysis. The following graph is a standard linear regression model plotted by the R language.

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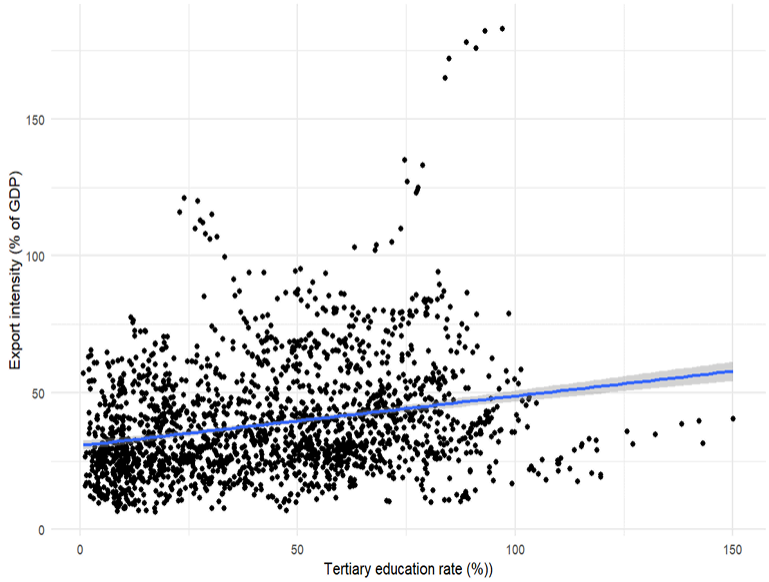


Figure 1. Tertiary education and export intensity linear regression (1998-2023)

As shown in Figure 1, despite a few outliners, the plot in the graph still indicates a linear correlation between the tertiary education rate $(X)$ and export intensity $(Y)$. The blue auxiliary line shows a tendency of how export intensity $(Y)$ can possibly develop with the increase in tertiary education $(Y)$. Each dot represents the status of a country of a certain year from 1998 to 2923.

Table 1 below shows the linear regression results between $X$ and $Y$, which validates the correlation between $X$ and $Y$, and also the possibility and accuracy of predicting $Y$ with $X$. The regression coefficient turns out to be 0.181 approximately with a p-value smaller than 0.01, which indicates every 1% change in tertiary education rate can roughly result to 0.181% change in export intensity with statistical significance. As the total effect linear regression is a simple linear regression, p-value for t statistic and for F statistic are the same. The p-value (F statistic) for regression coefficient is smaller than 0.01 which proves is a clear correlation between these variables, and the fitting is significantly better than without having this model. One the contrary, tertiary education rate can only explain 5.8% ( $R^2$ : 0.058) of the variance of the change in export intensity, which indicates education is a significant variable to export intensity but not the only driver.

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Table 1. Total effect linear regression results

| Linear regression statistics | Value |
|---|---|
| -Regression coefficient: x | 0.181 |
| -p-value, t-statistic | <0.01 |
| Std. Error: coefficient | 0.016 |
| Constant | 30.666 |
| p-value, t-statistic | <0.01 |
| Std. Error: constant | 0.838 |
| Observations | 2025 |
| $R^2$ | 0.058 |
| Adjusted $R^2$ | 0.058 |
| Residual Std. Error | 20.139 (df=2023) |
| F Statistic | 125.215 (df=1; 2023) |
| p-value, F-statistic | <0.01 |

## 4.2. Mediation analysis results

Based on the confirmed positive correlation between X and Y, we next carry on the Mediation analysis using involving all 3 factors. The following Table 2 comprises 2 models: one shows the influence that X exerts on M; the other is the combined influence X imposes on Y, through direct and mediated paths.

Table 2. Liner regression results for mediator model and direct effect model

| Linear regression statistics | Value (Mediator model regression, M~X) | Value (Direct effect model regression, Y~X+M) |
|---|---|---|
| Regression coefficient: X | 0.024 | 0.042 |
| p-value, t-statistic | <0.01 | 0.071 |
| Std. Error: coefficient | 0.001 | 0.023 |
| Regression coefficient: M | | 5.742 |
| p-value, t-statistic | | <0.01 |
| Std. Error: coefficient | | 0.686 |
| Constant | -0.920 | 35.946 |
| p-value, t-statistic | <0.01 | <0.01 |
| Std. Error: coefficient | 0.027 | 1.038 |
| Observations | 2025 | 2025 |
| $R^2$ | 0.523 | 0.090 |
| Adjusted $R^2$ | 0.523 | 0.089 |
| Residual Std. Error | 0.642 (df=2023) | 19.804 (df=2022) |
| F-statistic | 2217.943(df=1; 2023) | 99.744(df=2; 2022) |
| p-value, F-statistic | <0.01 | <0.01 |

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As regards the mediated effect model, the regression coefficient turns out to be 0.024 meaning every 1% increase in tertiary education rate can possibly lead to 2.4% increase in Export complexity index. In addition, this coefficient is proved to be statistically significant (p<0.01). Education, especially tertiary education is proved to contribute to more than half of the change in export complexity ( $R^2 = 0.523$ ). Furthermore, this model is a promising prediction for M, as the Residual Standard Error is only 0.642. Thus, the influence of tertiary education on export structure has been proved to be valid and strong.

Table 2 above also reveals the results of the direct effect linear regression model of $X$ , $M$ , and $Y$ with the coefficient of X being 0.042, and the coefficient of M being 5.742. This equation reveals that every 1% increase in tertiary education can possibly result in 4.2% increase in export intensity, while every unit in export complexity index can impose a more distinctive influence as significant as 574.2% in export intensity.

The mediated effect model presents to be significant and explanatory (p-value: F statistic <0.01), indicating there is a valid correlation between $Y$ and the variable entirety of $X$ and $M$ . However, this model can only cover 9.2% variation of $Y$ as showing by $R^2$ . An $R^2$ smaller than 0.3 is usually not recommended for prediction. The residual standard error of 19.804 also suggests the forecast can have a variance as considerable as 19.804 on average, which further proves this model is not suitable for prediction. P-value for t-statistic of $X$ is calculated as 0.071 which is bigger than 0.05 indicating $X$ is insignificant in the direct effect model, whilst $M$ is seen to be statistically significant (p-value, t-statistic of M <0.01).

With all the linear regression results, the following mediation model coefficient table can be drawn.

Table 3. Mediation analysis coefficient table

| Coefficient | Model/Path | p-value | Statistically significant? |
|---|---|---|---|
| $a$ | Mediation effect model | <0.01 | Yes |
| $b$ | Meditation effect model | <0.01 | Yes |
| $c$ | Total effect model | <0.01 | Yes |
| $c'$ | Direct effect model | 0.071 | No |

As showing Table 3, According to the causal step regression approach, if coefficients a, b, and c are all statistically significant while c' is insignificant when the mediator is independently considered, then this pattern indicates that it is a fully mediated effect through the export complexity index.

### 4.3. Robustness test results

To ensure the reliability of conclusion drawn from Causal steps regression, Table 4 is the robust test result with Bootstrap method. In particular, Bootstrap can fill in the blank of significance test of mediated effect, $a \times b$ . Furthermore, casual steps regression draws a conclusion with the

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assumption that mediated effect obeys normal distribution, which inaccuracy can be avoided by Bootstrap.

Table 4. Robustness test result with Bootstrap approach (5000 estimations)

| Mediation effect | Estimate | 95% CI lower | 95% CI upper | p-value |
|---|---|---|---|---|
| ACME (Average causal mediation effect) | 0.1395 | 0.1066 | 0.1724 | <0.001 |
| ADE (Average direct effect) | 0.0417 | 0.0007 | 0.0850 | 0.0476 |
| Total effect | 0.1812 | 0.1471 | 0.2169 | <0.001 |
| Proportion mediated | 0.7699 | 0.5765 | 0.9957 | <0.001 |

Bootstrap approach reveals a similar conclusion with a small distinction. This method also suggests there exists a strong mediated effect like the causal steps regression approach does. Nonetheless, it points out that the direct effect still remains significant and cannot be overlooked. Besides, Bootstrap suggests a proportion mediated effect of 77%.

## 5. Further discussion

This chapter wraps up the primary findings of this research so as to give highlight on the insights. Moreover, based on the conclusion, a few policy making suggestions are also rendered in the hope of resolving real life challenges especially for developing countries.

### 5.1. Primary research findings

There is a positive and strong correlation between tertiary education and export intensity, meaning education is a confirmed contributor to exports (p-value significant <0.01). On the other hand, education is clearly not the only one drive for export intensity as education in this model only seem to explain 5.8% of the variance of the change in export intensity ( $R^2 = 0.058$ ). Tertiary education accounts for more than half of the change in export structure which is measured by ECI in this research ( $R^2 = 0.523$ ). Besides, the influence education imposes on export intensity also seems to be realized mainly by export structure this channel (proportion mediated≈0.77 ).

Bootstrap approach and Causal steps regression method gives different conclusions on if export structure should be full mediation or partial mediation. Causal steps regression sees this as full mediation as the direct effect presents to be insignificant ( $c' = 0.071$ ), whilst Bootstrap approach sees the average direct effect as significant ( $c' = 0.0476$ ). As Casual steps regression assumes the residuals obey normal distribution and unsensitive to extreme values, which limitation is resolved by Bootstrap approach, we decide to go with the latter and admit the direct effect of tertiary education.

### 5.2. Extensions on existing theories

A number of theories have stated that education can boost exports and GDP through different channels, such as uplifting individual productivity and fostering innovation. But the majority did not quantify the influences from different channels and leave the subjects incomparable.

This research reveals the logical chain from tertiary education to export structure and, ultimately to export intensity with statistical grounds. We confirm that education is a clear but not dominant driving force for exports intensity, and the limited influence originated from education advantage is primarily passed down by raising the complexity in export structure.

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### 5.3. Insights into policy making

This study sheds light on the mechanism through which education contributes to export growth by enhancing the quality of human capital, offering significant implications for public policy. The findings suggest that education is not only a foundation for human development but also a strategic driver of export competitiveness. For policymakers, this underscores the importance of investing in higher education and vocational training, to strengthen a country's position in global trade. Moreover, the identified mediator of export structure suggests that diversity in higher education disciplines is one prerequisite to foster a coherent education–skills–exports pathway which ultimately supporting long-term, sustainable economic growth.

## 6. Conclusion

This study intends to figure out the interrelation among higher education, export structure, and export intensity on a global scale. Selecting higher education enrollment rate, ECI, and export intensity as the key variables, a mediation analysis is introduced to quantify the effect of higher education on export intensity through export structure as a mediator. The initial conclusion that exports structure plays full mediation is drawn by Causal step regressions approach, which later is modified into partial mediation by introducing Bootstrap method for a robustness test. Further research based on this study can test with other variables. Other education indicators such as tertiary education graduation rate, doctorate percentage of the popularity, are also worth consideration. Such replacement of variables is similarly meaningful for export-related variable selection. Apart from variable replacement, future study may try to focus on a longer period and to segment countries into different groups. Pre-grouping countries prior to analysis allows for better control of regional heterogeneity.

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