# Does Infrastructure Development Matter for Export Sophistication? Evidence from High-Income and Upper-Middle-Income Economies

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## Abstract

*Due to a paradigm shift from traditional to sophisticated products and a rise in the productivity level of countries, researchers focus on the factors that can affect the level of export sophistication. This study empirically investigates the impact of infrastructure development on export sophistication for a group of upper-middle-income (UMI) and high-income (HI) economies. To the best of our knowledge, this is the first study one which examines the nexus between on infrastructure development (INFRA) and the export sophistication of the aforementioned economies. For this, we develop a panel of 50 covering a period of 2010-2018 and compute export sophistication. Further, we apply PCA to a set of variables belonging to the information technology & telecommunication sector, transportation sector, and financial sector and construct the index of infrastructure development. This study applies the cross-sectional dependence (CD) test to avoid misleading results because of temporal and spatial correlation among economies. To tackle the problem of cross-sectional dependence, serial correlation, and heteroskedasticity, we apply the fixed effect with Drisc/Kraay standard error structure, panel corrected-standard error (PCSE), and feasible generalized least squares (FDLS). The results of this study show that rich economies' export basket contains a large share of goods produced by other rich economies whereas poor economies' major exports are primary goods produced by poor economies. Further, infrastructure development is a significant and robust driver of export sophistication. Therefore, countries should invest in infrastructure development to increase export sophistication.*


**Keywords:** Export Sophistication, Infrastructure Development, Transportation sector, Information technology & telecommunication sector, financial sector, Drisc/Kraay, FGLS, PCSE

**JEL Classification:** B17, B27, C23, F14, F11, H54

## 1. Introduction

In the current modern era of globalization, competition in international markets has intensified and countries are struggling to sustain their share in the international markets (Ekmen and Erlat, 2013; Fan et al. 2019). Because today's customer demands a cost-effective and useful product without compromising on quality. Before buying any product, today's customer considers the value for money and the value addition compared to already available products (Green,2022; Westbrook and Angus, 2021; Trivedi, 2021). Therefore, it is very difficult for a country to increase its share in international markets by exporting low-value-added and traditional products. To boost exports, the majority of countries are focusing on export upgrading and making their production process more sophisticated (Atasoy, 2021).

Previous studies identified many factors that could play a key role in export upgrading. Rodrik (2006) reports that integration among large and small companies and facilities for firms are important factors that affect export sophistication levels. According to Teng and Lo (2019), trade openness is a significant driver of export sophistication as it creates knowledge spillovers and technology diffusions. Braunerhjelm and Thulin (2008) report that research and development expenditures play a vital role in increasing the productivity level of goods and high-tech exports for a country. Similarly, investment in human capital is another source of export upgrading because it also increases the productive capacity of a country (Tebaldi, 2011). Weldemicael (2012a) advocates the positive role of institutional quality to increase export sophistication.

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Nonetheless, the literature offers inadequate information on the nexus between infrastructure development and export sophistication. Transportation facilities and innovation in the logistic sector are a significant source of upgradation of production structure and increase in productive capabilities of a country because it ensures fast, safe and low-cost delivery of raw materials to firms (Mathews and Stanely, 2022; Klein et al. 2022). In the same way, information technology keeps the firms updated on the preferences and requirements of the customer in the international markets and trends of international trade. In addition, information technology also provides information to producers about the availability of cheap raw materials and advanced technology along with production techniques to upgrade the production structure. Therefore, information technology is a source of knowledge spillover for domestic firms (Sun et al. 2011).

Similarly, the telecommunication sector plays a crucial role in connecting firms to the market and before the advent of the internet, it was the only source that helped firms to stay connected to international markets (Ahmad et al.2011). Likely, financial infrastructure also plays a vital role in the development of the industry as the financial sector is a primary supplier of funds to invest in companies' assets that are ultimately used for the upgradation of production structure. Furthermore, this sector eases the financial constraints of a firm to fulfill the requirements of operational and investment activities (Pan et al. 2021).

The purpose of this study is three-fold: First, to compute the export sophistication score. For this, we compute product-wise productivity and use it for the computation of export sophistication. Second, to study the impact of infrastructure development on export sophistication. For this, we develop a panel of 50 HI and UMI economies covering the period of 2010-2018. Further, we apply principal component analysis (PCA) on variables belonging to transportation (TRA), information technology & telecommunication (IT&T), and financial (FI) sectors to construct an index of infrastructure development (INFRA). All categories represent separate sectors and each sector in one way or another play a key role in the production process of a country, and: Third, to detect the cross-sectional dependence (CD) in the data because it is one of the most important diagnostic tests for static panel data to avoid misleading results (Menegaki, 2021). For this, we apply CD tests developed by Pesaran (2015) and Pesaran (2007). According to the information I have, this is the first study that attempts to investigate the role of infrastructure development to determine export sophistication for a group of UMI and HI economies.

Therefore, this study contributes to the literature by assessing the role of infrastructure development to determine the level of export sophistication. Furthermore, the focus is on UMI and HI economies and according to Islands et al. (2021), the volume of goods exchanged in 2020 among HI economies is US$6.6 trillion. Moreover, economies belonging to both income groups are the main trading markets for developing economies. Therefore, the implications of the study will be beneficial for a large community of the world. A recent announcement of a global infrastructure funding plan worth $600 billion by G7 countries to counter China's Belt and Road initiative further sheds light on the role of infrastructure development in international trade.

In addition, we apply fixed effects with Drisc/Kraay standard error structure, PCSE, and FGLS that account for spatial correlation, heteroskedasticity, and serial correlation in the model simultaneously (Driscoll and Kraay, 1998; Bailey and Katz, 2011; Bai et al.2019). Therefore, the results of the current study contribute to the literature by providing new evidence on the robust drivers of export sophistication in UMI and HI economies.

According to the findings of this study, countries that have a larger share of products with higher productivity have a high score of export sophistication. Further, infrastructure development promotes export sophistication in UMI and HI economies. In addition, human capital, physical capital, employers, trade openness, and, research and development expenditures are also significant and robust determinants of export sophistication. On the other hand, institutional quality and natural resources do not significantly affect export sophistication.

The organization of this study is as follows; The next section (2) contains the role of export sophistication in economic development followed by the theoretical framework (3) and data and methodology (4) respectively. In section 5 we provide empirical results and conclude them in section 6.

## 2. Literature Review

Hausmann et al. (2007) state that developing countries should produce products produced by developed economies to grow faster. According to literature" leapfrogging" and "window opportunity" are the possible ways to "catch up" with the "forerunners". In other words, less developed countries can produce those goods that are produced by developed economies by gaining from leapfrogging and window opportunity (Gerschenkron, 1962, 1963; Freeman, 1989). However, this could be possible by adopting the technology which is being used by developed countries. Furthermore, a gradual process of mastering the technology used by developed economies is a prerequisite to imitating the products produced by developed economies (Dosi et al. 1988; Freeman, 1987). However, countries started to take benefit from the second window opportunity proposed by Soete (1988) to upgrade their exports and increase their market shares. They proposed that forerunners catch up with latecomers because latter economies adopt new technology and the former creates a burden for themselves because of previous capital stock and institutional setup. The adoption of new technology opens some new windows of opportunity for latecomers and they successfully catch up with forerunners (Lee and Malerba, 2017).

Countries' export basket consists of a variety of different manufacturing, semi-manufacturing, and primary goods, and to produce a sophisticated product firms should upgrade their production structure and produce more sophisticated goods to avoid any loss as a result of an adverse external shock (Breitenbach et al. 2022). Can and Dugan (2017) state that a product that requires more knowledge, skills, experience, and education to be manufactured is called a sophisticated product. Atasoy (2021) states that countries prefer to upgrade their production structure in those sectors that are aligned with their factor endowments. However, classical models of trade, the H-O model and the Ricardian model, do not fully explain the pattern of specialization and export sophistication (Xu and Fu, 2013; Lectard and Rougier, 2018). Therefore, other than the fundamental inputs, which are the key input of export sophistication and specialization, researchers identified some other factors that determine the export sophistication of countries (Fu et al. 2012; Fu and Going, 2011).

According to endogenous growth theories, knowledge creation and knowledge accumulation are significant determinants of export sophistication. The primary sources of knowledge creation are human capital and research & development activities that enhance the productive capacity of a firm and country (Lucas, 1988; Romer, 1990; Schott 2008). Another source of knowledge spillover and technology diffusion is international trade which can affect the level of export sophistication. Likely, government efforts to facilitate the business community increase the number of producers in a country. A country with a higher ratio of employers to employees in the industrial sector produces more sophisticated products than others because of more employed workers in the manufacturing sector (Gala et al. 2018). Similarly, the role of institutional quality is also important for export sophistication because it protects property rights and ensures rule of law (Anand et al. 2012). However, Weldemicael (2012a) states that institutional quality matters only for the manufacturing industry.

It can be concluded from the above discussion that the literature provides rigorous information about the assessment of the determinants of export sophistication. However, the role of infrastructure is not widely discussed in the literature as a determinant of export sophistication. Infrastructure plays a vital role to increase the volume of trade among countries. Researchers focus on the role of information technology & telecommunication infrastructure, financial infrastructure, and transportation infrastructure as a source of increase in international trade. Clarke (2002) examined the relationship between the use of the internet and exports and finds that companies with internet facilities export more than firms without internet facilities. Similarly, Ahmad et al. (2011) studies the impact of the use of computers, the internet, and telephones on the bilateral trade of Malaysia with its trading partners and finds that information technology &

telecommunication has a positive and significant impact on Malaysia's bilateral trade. Paudel and Alharti (2021) investigate the nexus between financial development and export performance in Nepal and concludes that financial development and integration of financial markets have a negative relationship with the export performance of Nepal‡. Ur et al. (2021a) conclude that Chinese export sophistication is positively affected by China's trade-related infrastructure. Similarly, a study by International Monetary Fund (2022) states that Thailand showed a remarkable improvement in digitalization and information technology sectors, particularly in the post-COVID-19 era. These efforts significantly improved the export sophistication score of Thailand. Fan and Huang (2018) report that infrastructure development plays an important role to determine the export sophistication of the manufacturing sector in a group of 85 economies. Likewise, Paloni and Ebireri (2016) show that the banking sector is one of the primary sources of liquidity for firms, funds required to produce innovative products, and adoption of advanced technology. Therefore, the banking sector has a positive association with the production of sophisticated products. Although former studies focus on these sectors, they do not incorporate these sectors simultaneously to determine the level of export sophistication. Hence, the current study uses these sectors simultaneously and develops an index of infrastructure development, which shows a broader picture regarding infrastructure development, to analyze the association between infrastructure development and export sophistication.

# 3. Methodology and Data

## 3.1 Theoretical Framework

As the primary purpose of current research is to empirically examine the impact of INFRA on export sophistication for a panel of HI and UMI. Physical capital and natural resources are fundamental inputs that directly contribute to the operational and production activities of a firm to upgrade its exports. Another important driver of export sophistication is the number of firms. Because entrepreneurship is an important factor of production that efficiently organizes the resources of a corporation. (Xu and Fu, 2013; Hausman et al. 2007).

Human capital contributes to the productivity of a firm which is the ultimate source of export upgrading. Likely, research and development activities enhance the productivity of factors of production, therefore; firms with a higher rate of R&D succeeded in upgrading their exports. Both aforementioned variables are the source of domestic knowledge spillover (Aghion and Howitt,1992; Sakurai et al. 1996). Similarly, international trade plays an important role in the reduction of the cost discovery process for domestic firms because it is a source of foreign knowledge and positive externality (Teng and Lo, 2019; Hausman and Rodrik, 2003). Institutional quality is also a potential determinant of export sophistication because it reflects the capacity to absorb knowledge in an economy.

According to Fan et al. (2018), internet access facilitates a firm during the production of sophisticated products. Ur et al. (2021) state that logistic performance measured by trade-related infrastructure connects firms to national and international markets and increases firms' profitability by reducing delivery costs and ensuring the availability of cost-effective inputs. Sridhar and Sridhar (2007) report that telecommunication is a source of reduction in the cost of production and surges in reinvestment by firms. Further, it increases the productivity of firms, therefore; it enhances export sophistication.

In light of previous studies and theories and by following the methodology of Atasoy (2021) and Zu and Fu (2013), the basic empirical model is as follows

$$EXPY_{it} = \beta_0 + \beta_1 R\&D_{it} + \beta_2 HC_{it} + \beta_3 EMPL_{it} + \beta_4 CAP_{it} + \beta_5 TO_{it} + \beta_6 IQ_{it} + \beta_7 PWLA_{it} + \beta_8 INFRA_{it} + \mu_{it} \quad (1)$$

where $EXPY$ is export sophistication score, $R\&D$ is research and development expenditures, $HC$ is human capital, $EMPL$ is a proxy of producers, $CAP$ is physical capital, $TO$ is international trade, $IQ$ is

‡ This study states that the performance of both financial system and financial institutions in Nepal is very poor and consequently the role of financial infrastructure is adversely affecting the export sector of Nepal.

institutional quality, $PWIA$ is per worker land area as a proxy of natural resources, $INFRA$ is the index of infrastructure development, $\mu$ is an error term, $t$ is time and $i$ is for cross sections.

Due to the unavailability of data for several countries, we constructed a panel of 50 economies of which 35 countries belong to the HI group and 15 countries belong to UMI economies. The time covered by this study is 2010-2018 to avoid the impact of the global financial crisis of 2007-2008.

### 3.2 Econometric Methodology

Due to panel characteristics, this data may suffer from the problems of both time series and cross-section data such as serial correlation, heteroskedasticity, cross-sectional dependence, etc. To detect these problems, the current study will apply the necessary diagnostic test proposed by previous studies for robust and efficient estimation results.

#### a. Test of heteroskedasticity and Serial correlation

Due to heteroskedasticity and serial correlations, standard errors of estimates may inflate and leads to inefficiency of results. Breusch and Pagan (1979) propose a test to detect heteroskedasticity in the data. Later on, Cook and Weisberg (1983) extends the work of Breusch and Pagan (1979) and developed a test based on the LM test principle to detect heteroskedasticity in the data. Similarly, Born and Breitung (2016) propose LM tests to detect a serial correlation of order k in the data. Therefore, to avoid inefficient results we apply both tests before estimating equation (1).

#### b. Cross-Sectional Dependence

Cross-sectional dependence is a problem of panel data that emerges because of the common social, cultural, and behavioral values of countries included in a panel. Due to these common characteristics, cross-country error terms correlate with each other over time. In the presence of this problem fixed effect and random effect and the GMM model may provide misleading results (Driscoll and Kraay, 1998; Munir et al. 2016; Sarafidis and Robertson, 2009). Therefore, in the first stage, this study will apply the cross-sectional dependence (CD) test developed by Pesaran (2008). The methodology of Pesaran's CD test is below:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=j+1}^{N}\hat{\rho}_{ij} \dots\dots\dots(2)$$

The null hypothesis of this test is that cross-sections are independent. Pesaran (2015) developed another test to determine the cross-sectional dependence in panel data under the null hypothesis of cross-sections are weekly dependent and the alternative hypothesis of cross-sections are strongly dependent. We also apply this version of the test to detect cross-sectional dependence in our model.

#### c. Fixed effects and random effects

The fixed effects model is a technique to analyze the panel data used in a case when one is interested to find the impact of a factor that varies with time. It assumes that differences in cross-sections are systematic and do not affect the dependent variable. Therefore, independent variables are the only source of change in dependent variables (Stock & Watson, 2003). The equation of the fixed effect model is given below

$$Y_{it} = X\beta + Z\gamma + \alpha + \mu_{it} \dots\dots\dots(3)$$

where $\alpha$ represents unobservable differences across cross-sections, $Y$ is the dependent variable of the model, $X$ is the matrix of independent variables, $Z$ is the matrix of time dummies, $\mu$ is the residual, *i* denotes cross-section, and *t* denotes time.

However, if someone is interested to find the impact of time-invariant factors on the dependent variable then the equation will be transformed into a random effect model. This model assumes that differences among cross-sections are random and affect dependent variables (Green, 2008). The equation of the random effect model is below

$$Y_{it} = X\beta + Z\gamma + v_{it} \dots\dots\dots(4)$$

where, $v_{it} = \alpha + \mu_{it}$.

However, in the presence of cross-sectional dependence, results of fixed effects and random effects may be invalid and inefficient. In this case, researchers suggest the use of the fixed/random effects model with Drisc/Kraay standard error structure, PCSE, and FGLS. The advantage of these methods is that they tackle the problem of serial correlation, heteroskedasticity, and contemporaneous correlation simultaneously (Hoechle, 2007; Bailey & Katz, 2011; Bai et al., 2019).

## d. Mundlak specification test

To choose between fixed and random effects models to estimate equation (1) with Drisc/Kraay error structure we applied Mundlak's (1978) test as an alternative to the Hausman specification test. The advantage of this test is that it can be applied in case of heteroskedastic errors and errors with intergroup correlation. The methodology of the Mundlak test explained in Mundlak(1978) is as follows;

$$y_{it} = x_{it}\beta + \alpha_i + u_{it} \quad (5)$$

where $$\alpha_i = \bar{x}_i\theta + v_i \quad (6)$$

By applying expectations on both sides, equation (6) will convert into equation (7).

$$E\left(\alpha_i / x_i\right) = \bar{x}_i\theta \quad (7)$$

Now we can rewrite equation (5) after combining equations (5) and (6) as below;

$$y_{it} = x_{it}\beta + \bar{x}_i\theta + v_i + u_{it} \quad (8)$$

$$E\left(y_{it} / x_{it}\right) = x_{it}\beta + \bar{x}_i\theta \quad (9)$$

The null hypothesis of this test is as follows;

$$H_o:\ \theta = 0 \quad (10)$$

If $H_0$ is accepted then the random effects will be suitable otherwise the fixed effects will be the preferred model to analyze the data.

## e. Data Description and Sources

**Measurement of export sophistication**

To measure export sophistication, we follow the methodology of Rodrik (2006) and Hausmann et al. (2007) to compute export sophistication. Andreoni (2011a) documents that export sophistication represents the productive capacity of a country and countries with the export of less sophisticated and primary goods may be caught in the middle-income trap (Felip et al. 2014). Jankowska et al. (2012) show that export sophistication creates learning by doing effects and promotes economic growth in the economy. The formula to measure product level sophistication in the first stage for a product k in year *t* is below;

$$PRODY_k = \sum_i \left\{ \frac{\left(x_i^k / X_i\right)}{\sum_i \left(x_i^k / X_i\right)} Y_i \right\} \quad (11)$$

where, $Y_i$ is the GDP Per Capita, PPP (Constant 2017 international \$) for country i, $x_i^k$ is the value of export of product k for country i, $X_{i,t}$ is the value of total exports for country i. Therefore, the numerator of equation (11) is the share of product k in total exports of country i, and the denominator is representing the share of product k in total exports of the rest of the countries that are exporting product k. Finally, the PRODY is simply a weighted mean of GDP per capita of all those countries that are exporting product k and weight is equal to the revealed comparative advantage (RCA) of a country in product k to normalize the sum of RCA equal to one. Therefore, by construction, a product will be more productive if it is exported by developed countries.

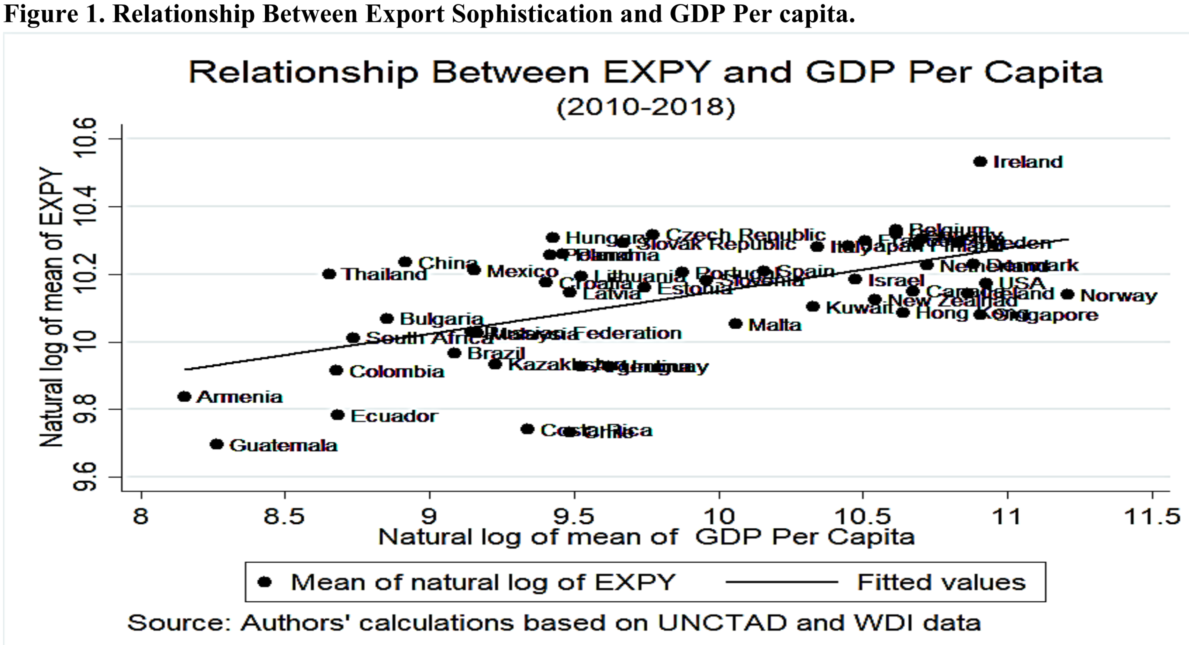
In the second stage, this study uses the below formula to transform product-level sophistication into country-level export sophistication.

$$EXPY_{i,t} = \sum_i \left\{ x_{i,t}^k / X_{i,t} \right\} PRODY_k \quad (12)$$

EXPY is export sophistication computed by the weighted average of productivity associated with each product, $k$, exported by country i in year t. Therefore, EXPY shows the quality of the export basket of a country (Hausmann et al., 2007). Later on, Felipe et al. (2010), among others, defined it as the income level associated with the export basket of a country. To compute it, initially, the current study used the data of 259 products using the Standard International Trade Classification (SITC) Rev. 3 at the 3-digit level available at UNCTADstat (https://unctadstat.unctad.org/EN/). Furthermore, to measure the productivity of products this research used GDP Per Capita, PPP (Constant 2017 international $) obtained from World Development Indicators covering the period 2016-2108. However, the current research computed the export sophistication of 50 countries from 2010 to 2018 as the global financial crisis of 2007-08 severely disturbed global value chains and the composition of the export basket of countries (Antras, 2019).

The names of countries with export sophistication scores are provided in table A1 in the appendix. The top 5 countries with a higher level of export sophistication score have a relatively good quality of inputs such as human capital and physical capital. Therefore, such economies have more share of productive goods in their export basket (Hausman et al. 2007). For example, Pharmaceuticals, chemicals, technical apparatus, electrical machinery, aircraft, and spacecraft are among the major exports of Ireland which has the highest average score of export sophistication in the current panel of economies. Similarly, the country with the second highest score in this current panel of economies is Belgium which has vehicles, pharmaceuticals, machinery, plastic articles, electrical machinery, chemicals, and steel as major components of its export basket. These products are produced and exported by other developed economies as well, therefore, countries with a large share of these products will have a high value of export sophistication score. According to table A1 in the appendix, the country with the lowest score of export sophistication among the group of economies used by the current study is Guatemala. The major exports of Guatemala are primary products such as bananas, coffee, raw sugar, palm oil, etc. Major exporters of primary products are developing economies, therefore, countries having more share of products produced by developing economies have a low level of export sophistication. Figure 1 illustrates a positive relationship between export sophistication and GDP per capita.

**Figure 1. Relationship Between Export Sophistication and GDP Per capita.**




To capture the impact of infrastructure development, this study applies principal component analysis (PCA) to transportation, financial, and information technology & telecommunication-related variables. All these sectors facilitate firms in the production process and trading activities with the rest of the economies. The scree plot of eigenvalues in descending order is provided in figure 2. As per figure 2, the first, second, and third eigenvalues are greater than one, therefore, we construct an index of infrastructure development based on the first two components. The detailed definition and data source of variables are presented in table A2 in the appendix.

**Figure 2. Scree plot of eigenvalues**

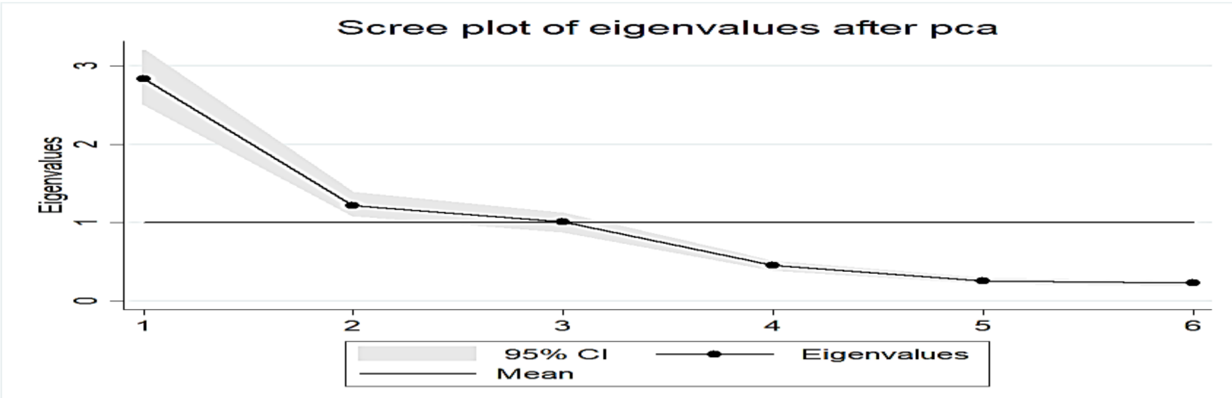



Table 1 provides descriptive statistics of the data. The average value of EXPY of this panel is 25500.77 (2017 PPP $) with a maximum of 39871.54 and a minimum of 12256.28. Similarly, the index of infrastructure development constructed by PCA has a mean value of 0.13 and the maximum and minimum value of the index is -2.15 and 2.53 respectively.

**Table 1. Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| EXPY | 450 | 25500.57 | 4302.15 | 12256.28 | 39871.54 |
| R&D | 450 | 1.40 | 1.02 | 0.02 | 4.94 |
| HC | 450 | 3.12 | 0.43 | 1.76 | 4.15 |
| EMPL | 450 | 3.72 | 1.24 | 0.46 | 6.91 |
| CAP | 450 | 6637082 | 13600000 | 46240.91 | 93500000 |
| TO | 450 | 105.32 | 76.51 | 22.49 | 442.62 |
| IQ | 450 | 0.80 | 0.97 | -1.83 | 2.96 |
| PWLA | 450 | 0.03 | 0.06 | 0.0001 | 0.32 |
| INFRA | 450 | 0.13 | 0.90 | -2.15 | 2.53 |

Source: Authors' calculations

Table 2 contains the values of pairwise correlation which explains the nature and strength of the linear association between 2 variables. According to the values in the first column of Table 2, INFRA has a positive correlation with export sophistication. All control variables have a positive linear association with export sophistication except land area which has a negative correlation with export sophistication. Although the value of correlation among all independent variables is small, the value of correlation between INFRA and CAP is near 1. Therefore, to avoid the problem of multicollinearity we transform CAP into a growth rate form for regression analysis.

## 4. Results and Discussion

To analyze the impact of INFRA on export sophistication, initially, we test the existence of heteroskedasticity, serial correlation, and cross-sectional dependence in the data to avoid misleading results.

According to the results of table 4, CD and heteroskedasticity exist in the data because the probability value of tests used to detect both of them is less than 0.05 which rejects the null hypothesis of both tests. However, we accept the null hypothesis of the test of serial correlation which implies that there is no serial correlation in the data analyzed by the current study. In this case, neither fixed effect nor random effect with OLS standard error structure is a suitable technique to analyze the data (Bartels, 2008).

**Table 2. Pair-wise correlation between variables**

| Variables | EXPY | R&D | HC | EMPL | CAP | TO | IQ | PWLA | INFRA |
|---|---|---|---|---|---|---|---|---|---|
| EXPY | 1.00 | | | | | | | | |
| R&D | 0.54 | 1.00 | | | | | | | |
| HC | 0.47 | 0.58 | 1.00 | | | | | | |
| EMPL | 0.21 | 0.13 | 0.08 | 1.00 | | | | | |
| CAP | 0.31 | 0.35 | 0.11 | 0.06 | 1.00 | | | | |
| TO | 0.21 | -0.04 | 0.22 | 0.11 | -0.28 | 1.00 | | | |
| IQ | 0.50 | 0.65 | 0.58 | 0.27 | 0.04 | 0.30 | 1.00 | | |
| PWLA | -0.16 | -0.13 | 0.00 | -0.11 | -0.08 | -0.66 | -0.14 | 1.00 | |
| INFRA | 0.38 | 0.51 | 0.27 | 0.07 | 0.95 | -0.27 | 0.24 | -0.04 | 1.00 |

Source: Authors' calculations

Therefore, this study will apply the fixed effects/random effects model with Drisc/Kraay standard error structure. The selection of techniques between random and fixed effects with Drisc/Kraay standard error depends on the results of the Mundlak specification test. According to the results of the Mundlak test, the fixed effects is a more appropriate technique for this data set. The results of these tests are presented in table 3**.**

**Table 3: Cross-sectional dependence and Hausman specification**

| Test | Probability value | Decision |
|---|---|---|
| Breusch-Pagan / Cook-Weisberg ($H_0$: Constant variance) | 0.0029 | Heteroskedasticity exists in the data |
| Born and Breitung ($H_0$: No first-order serial correlation) | 0.276 | Serial correlation does not exist in the data. |
| Pesaran's test of weak cross-sectional dependence ($H_0$: cross sections are weekly independent) | 0.0000 | Strict cross-sectional dependence exists in the data. |
| Pesaran's test of cross-sectional dependence ($H_0$: cross-sections are independent) | 0.0000 | Cross-sectional dependence exists in the data. |
| Mundlak's specification test ($H_0$: Random effects) | 0.0151 | The fixed effect model is more appropriate to analyze the data. |

Source: Authors' calculations.

**Note:** The corresponding values for Pesaran, Mundlak, Breusch-Pagan / Cook-Weisberg, and Born and Breitung tests are *p-values.*

The first column of table 4 contains the results estimated by OLS. According to the results of OLS, all variables are significant except IQ and CAP. However, OLS results may be misleading in panel data because of heteroskedasticity and correlation with country-unobserved effects. Therefore, to avoid misleading results, we applied the fixed effects with Drisc/Kraay standard error structure which tackles the problem of spatial cross-sectional dependence efficiently. Another advantage of this technique is that it deals with serial correlation, heteroskedasticity, and cross-sectional-dependence simultaneously (Hoechle, 2007). In addition, to avoid the possibility of endogeneity, the current research considered the first lags of all regressors during regression analysis. The results of this technique are presented in table 5 in column 2 with the name of fixed effects with Drisc/Kraay.

According to the results of column 2, the coefficient of the index of infrastructure development (INFRA) is significant and positive which implies that INFRA is a significant driver of export sophistication. 1 unit increase in the value of INFRA leads to an increase in export sophistication by 0.07%. All control variables are also significant and have expected signs except IQ and PWLA which are insignificant. Infrastructure is a set of physical and organized systems of a nation consisting of buildings, roads, railway tracks, communication, and information technology that facilitate firms involved in the production of goods and services. Therefore, infrastructure development is a source of reduction in the cost discovery process for firms that involve in the production of sophisticated products. It serves as a source of information for a firm to upgrade the production structure and goods as per the preferences of international customers and the trends in international markets (Atasoy et al.2021).

**Table 4. Estimates of Drisc/Kraay, PCSE, and FGLS**

| Variables | (1) Pooled-OLS | (2) FE with Drisc/Kraay | (3) PCSE | (4) FGLS |
|---|---|---|---|---|
| R&D | 0.0589*** | 0.0235** | 0.0705*** | 0.0538*** |
| | (0.0119) | (0.00926) | (0.00826) | (0.0130) |
| HC | 0.1411** | 0.0974* | 0.2930*** | 0.2670** |
| | (0.0714) | (0.0513) | (0.0866) | (0.105) |
| EMPL | 0.0163*** | 0.0350*** | 0.0202*** | 0.0198*** |
| | (0.0057) | (0.0081) | (0.0064) | (0.0047) |
| CAP | 0.368 | 0.858*** | 0.144 | 0.566** |
| | (0.466) | (0.145) | (0.358) | (0.248) |
| TO | 0.0007*** | 0.0003*** | 0.0007*** | 0.0007*** |
| | (0.0002) | (0.00006) | (0.0002) | (0.0001) |
| IQ | 0.0134 | -0.0123 | 0.0176*** | -0.0010 |
| | (0.0126) | (0.0123) | (0.0050) | (0.0087) |
| PWLA | 0.0139** | 0.0399 | 0.0017 | 0.0129* |
| | (0.00694) | (0.0482) | (0.0072) | (0.0067) |
| INFRA | 0.0503*** | 0.0750*** | 0.0296** | 0.0487*** |
| | (0.0096) | (0.0180) | (0.0137) | (0.0101) |
| Constant | 9.789*** | 9.975*** | 9.504*** | 9.629*** |
| | (0.0917) | (0.258) | (0.123) | (0.135) |
| Observations | 400 | 400 | 400 | 400 |
| R-squared | 0.422 | | | |
| Number of countries | | 50 | 50 | 50 |

**Note:** ***, **, and, * show 1%, 5%, and 10% levels of significance. Standard errors are in parenthesis.

Further, INFRA facilitates a firm by providing it access to cheap raw materials, intermediate goods, and advanced technology used to produce a final good. In addition, INFRA also plays a vital role in the cost-effective and quick delivery of output in the markets (Rehman et al.2021). Due to aforesaid facilities in the results of infrastructure development, producers encourage to upgrade their products from the existing level because of a reduction in the cost discovery process (Fan et al.2018).

Columns 3 of table 4 show the results of equation (1) estimated by panel-corrected standard errors. This technique also accounts for heteroskedasticity, serial correlation, and cross-sectional dependence in the data. Once again, the coefficient of INFRA is positive and significant. These estimates are similar to the estimates of the Drisc/Kraay method provided in column 2 except for the coefficient of IQ which is significant this time. Finally, column 4 of table 4 contains the estimate of equation (1) estimated by feasible generalized least square. The coefficient of INFRA has the same sign and level of significance as in the previously provided results of Drisc/Kraay and PCSE.

### 4.1 Sensitivity Analysis

According to Hoechle (2007), Drisc/Kraay method performs relatively better than PSCE and FGLS when the number of cross-sections exceeds the number of years. Therefore, we apply fixed effects with Drisc/Kraay standard error structure for sensitivity analysis. To analyze the sensitivity of results we follow a specific to general model approach. In the first model, we estimated an equation with infrastructure development proxy (INFRA) and fundamental determinants inputs CAP , PWLA, and EMPL. All variables are significant and have positive coefficients except per worker land area (PWLA) which is insignificant. In the second model, to capture domestic knowledge creation we included 2 additional variables HC and R&D. Again, all variables are significant and have positive signs. In the third model, this study included international trade to capture the impact of foreign knowledge on export sophistication which is significant. Finally, in the last model, we added variables IQ to control domestic capacity to absorb foreign and domestic knowledge. However, IQ is insignificant. These results are similar to the results provided in column 2 of table 4. The coefficient of INFRA has positive sign in alternative specifications of the model. Therefore, INFRA is a robust driver of export sophistication.

**Table 5. Sensitivity Analysis of estimates of Fixed effects with Drisc/Kraay error structure**

| Variables | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| EMPL | 0.0348*** | 0.0355*** | 0.0355*** | 0.0350*** |
| | (0.00804) | (0.00809) | (0.00796) | (0.00813) |
| CAP | 0.887*** | 0.990*** | 0.860*** | 0.858*** |
| | (0.161) | (0.166) | (0.138) | (0.145) |
| PWLA | 0.0448 | 0.0749 | 0.0311 | 0.0399 |
| | (0.0481) | (0.0397) | (0.0399) | (0.0482) |
| HC | -- | 0.0862* | 0.105** | 0.0974* |
| | | (0.0443) | (0.0409) | (0.0513) |
| R&D | -- | 0.0260** | 0.0231** | 0.0235** |
| | | (0.0100) | (0.00872) | (0.00926) |
| TO | -- | -- | 0.0004*** | 0.0004*** |
| | | | (0.0001) | (0.0001) |
| IQ | -- | -- | -- | -0.0123 |
| | | | | (0.0123) |
| INFRA | 0.0836*** | 0.0740*** | 0.0717*** | 0.0750*** |
| | (0.0124) | (0.0159) | (0.0166) | (0.0180) |
| Constant | 10.17*** | 10.16*** | 9.913*** | 9.975*** |
| | (0.210) | (0.210) | (0.201) | (0.258) |
| Observations | 400 | 400 | 400 | 400 |
| Number of groups | 50 | 50 | 50 | 50 |

**Note**: ***, **, and, * show 1%, 5%, and 10% levels of significance. Standard errors are in parenthesis.

## 5. Concluding remark and recommendations

The purpose of the current study was threefold: First, to compute export sophistication score and to construct an index of infrastructure development: Second to analyze the impact of infrastructure development on export sophistication, and: Third to detect the cross-sectional dependence which emerged in the data of countries with similar characteristics over time. To compute export sophistication this study computes product-wise productivity and income level associated with the export basket of a country. Similarly, to measure infrastructure development the current research focuses on transportation, financial, and information technology & telecommunication for a panel of 15 upper-middle-income and 35 high-income economies covering the period of 2010-2018. In the light of the CD test and Mundlak specification test, the current study analyzes the data by fixed effect with Drisc/Kraay standard error structure which tackles the problem of cross-sectional dependence, serial correlation, and heteroskedasticity simultaneously. According to the results of this model, infrastructure development is a significant driver of export sophistication. All sectors of infrastructure development used by this study play a vital role to determine export sophistication.

The literature provides immense information on the role of export sophistication in the development of countries. Countries that successfully managed to upgrade their export basket grew faster than countries with low-sophisticated export baskets. The results of the current study suggest countries with a low sophisticated export basket should upgrade their infrastructure to reduce the discovery cost of firms. For this, countries should improve their transport-related infrastructure including roads, railways, ports, etc. to make sure fast, safe, and cheap availability of inputs and delivery of output in international markets. The role of government is indispensable for the improvement of logistic performance because the private sector cannot build it by itself.

Another sector with the potential to boost export sophistication as a facilitator is information technology & telecommunication. In the current modern era, it is the leading source of information about the preferences of customers, trends in international trade, access to advanced technology, and availability of cheap raw materials. Therefore, the current study encourages firms and governments to promote the culture of digitalization in the industry. In addition, for the flourishment of the information technology & telecommunication sector government should provide incentives to this sector and impose policies for the easy adoption of digitalization by the private sector. Likely, the financial sector is one of the primary sources of funds required to finance investment activities. The results of this study suggest developing economies should impose prudential regulations on the financial sector of the economy and provide incentives to private investors to invest in the financial sector. In addition, countries should focus on human capital accumulation and research and development expenditures to increase the productivity of fundamental inputs. Similarly, countries should make their economies more open to trade and impose liberal policies to increase the volume of international trade.

For future research, the current study encourages researchers to identify the factors that can affect the level of export sophistication in the manufacturing sector. In addition, to explore the role of infrastructure development researchers should focus on lower-middle-income and low-income economies as well.

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**Appendix:**

**Table A1. Country-wise Average export sophistication score**

| Country | EXPY | Country | EXPY | Country | EXPY | Country | EXPY | Country | EXPY |
|---|---|---|---|---|---|---|---|---|---|
| Ireland | 37477 | Japan | 29242 | Thailand | 26905 | Norway | 25303 | Brazil | 21307 |
| Belgium | 30673 | Italy | 29177 | Lithuania | 26744 | New Zealand | 24909 | Kazakhstan | 20609 |
| Germany | 30266 | Panama | 28499 | Israel | 26467 | Kuwait | 24423 | Uruguay | 20504 |
| Czech Republic | 30248 | Poland | 28476 | Slovenia | 26431 | Hong Kong | 24005 | Argentina | 20475 |
| Hungary | 29971 | China | 27865 | Croatia | 26234 | Singapore | 23874 | Colombia | 20216 |
| Austria | 29851 | Denmark | 27689 | USA | 26178 | Bulgaria | 23566 | Armenia | 18728 |
| France | 29711 | Netherland | 27585 | Estonia | 25838 | Malta | 23194 | Ecuador | 17724 |
| Sweden | 29509 | Mexico | 27180 | Canada | 25569 | Russian Federation | 22655 | Costa Rica | 16997 |
| Slovak Republic | 29467 | Spain | 27134 | Latvia | 25454 | Malaysia | 22566 | Chile | 16874 |
| Finland | 29279 | Portugal | 27019 | Iceland | 25418 | South Africa | 22289 | Guatemala | 16237 |

**Table A2. Description of Variables and data sources**

| Abbreviation | Variable | Source |
|---|---|---|
| **Variables used to construct the index of Infrastructure Development (INFRA)** | | |
| TRA | Natural log of quality of trade and transport-related infrastructure. | World Bank |
| IT | Natural log of the number of persons using the internet | ITU, World Bank |
| FTS | Natural log of Fixed telephone subscriptions | ITU, World Bank |
| FBS | Natural log of Fixed broadband subscriptions | ITU, World Bank |
| MCS | Natural log of Mobile cellular subscriptions | ITU, World Bank |
| FI | Natural log of commercial bank branches | IMF, World Bank |
| INFRA | Index of Infrastructure Development | Authors' calculation |
| **Dependent and Control Variables of the Model used by the current study** | | |
| EXPY | Natural log of export sophistication score. | Authors' calculation |
| CAP | Real physical capital stock (2017 US$) | Penn World Table, version |
| EPMA | Employers (% of total employment) | ILO, WDI |
| PWLA | Per worker land area | WDI |
| R&D | Research and development expenditures (% of GDP) | WDI |
| HC | Natural log of Human Capital Index | Penn World Table, version |
| IQ | Rule of Law index | WGI |
| TO | Imports plus exports (% of GDP) | WDI |