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DEVELOPING TIME-SERIES NEXUS BETWEEN ECONOMIC OPENING-UP AND INDUSTRIAL UPGRADING IN GVC OF CHINA-NEW INSIGHT FROM WAVELET APPROACH

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A B S T R A C T

This study unravels the connectedness between spread of opening-up on industrial upgrading of Chinese economy, within a time-frequency domain, by employing yearly data from 2001 to 2014. . Economic opening-up was calculated using the trade openness and investment openness, while industrial upgrading in GVC was indicated by product, process and skill upgrading. Correlation analysis, wavelet coherence plots and granger-causality analysis are the analytical tools applied in this paper. Our findings show strong noises of red color between economic opening-up and product, process and skill upgrading in global value chain, for long run investment horizons; while in the medium run investment horizon, mild to strong co-movement was evidenced between economic opening-up and indicators of industrial upgrading in GVC. The results of granger causality analysis suggest that the economic opening-up of a country like China may pose significant short and long run impact on product, process and skill upgrading. Varying patterns of connectedness in short and long run investment horizons may declare opening-up of China as the source of economic growth through upgrading of industrial structure for countries like China. This drags the concentration of policymakers for short and long run responses to opening-up of the economy.

A R T I C L E I N F O

Keywords:
Wavelet Coherence, Product Upgrading, Process Upgrading, Skill Upgrading, Granger Causality

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1. INTRODUCTION

1.1 Economic Opening-up of China and Industrial Upgrading

The rapid development of the China's economy draws much attention of the world as its annual average growth rate of GDP has reached 14.90% from 1978 to 2018. The increasing integration of China into the world economy has been driven by the rapid expansion of its international trade and by large foreign direct investment inflows (Zhang and Daly, 2011). These two trends appear closely interrelated. FDI has been a major determinant of the opening up of China's economy: it has strongly contributed to promote competition in the domestic market and determined the evolution of foreign trade. The degree of foreign capital entry will have an important impact on industrial upgrading of the host country (Kee and Tang, 2016). The extension of FDI means the high-end technology brought by multinational enterprises, which will contribute to the imitation of technological innovation for the developing countries (Barrios et al., 2005). It is well-known that, through productivity spillover effects, FDI can potentially improve the export performance of firms located in developing countries (Anwar and Sun, 2018). In case of China, FDI has played a major part in the opening up of country's industry and in its integration into the international division of labor (Lemoine, 2000). Thus, opening up of China to the outside world has had a significant positive impact on country's economic growth (Zhang et al., 2019), as economic opening up of a country encourages domestic firms to invest in new technologies, which contributes to export quality upgrading (Anwar and Sun, 2018). Furthermore, China's opening up policy has aimed at promoting exports, while protecting the domestic market (Lemoine, 2000).

From the beginning of the 21st century, China has become a major player in the international economy by vigorously developing resource-intensive and labor-intensive industries. Basically, the development of a regional economy is the development of industry (Wang et al., 2020). China has attained record levels of foreign capital inflows and export growth utilizing a more strategic, statist approach to its development (Gereffi, 2009), and the country is catching up quickly through augmenting its factor endowments and upgrading industries (Lin and Wang, 2012), and the rates of upgrading are quite escalating (Assche and Gangnes, 2010). From the onset of its reforms and associated opening up to the global economy in the early eighties, China has made the attraction of labor-intensive export processing activities a key element of its export-led development strategy (Naughton and Lardy, 1996). If exports are to contribute to future growth, it is believed that export processing firms in China will have to move up the value chain and specialize in more capital- and skill-intensive activities (Lin and Chang, 2009). Further, Neoclassical growth theory holds that trade openness can promote capital formation and the enhancement of resource allocation efficiency, thus facilitating the improvement of economic growth quality (Kong et al., 2021). Moreover, there is a positive and powerful complementary relationship between trade openness and capital formation (Keho, 2017). New growth theory posits that trade openness mainly elevates economic growth quality through accelerating technical progress and boosting factor productivity (Robert, 1988). The liberalization of international trade reduces anti-export bias and makes exports more competitive in international markets (Joshi and Little, 1996). Thus, economic opening up of a country will promote the allocation of domestic resources and the adjustment of industrial structure.

1.2 Industrial Upgrading in GVC

Upgrading was initially defined as the ability to make better products, to make them more efficiently, or to move more into skilled activities (Porter, 2011). It is important to understand the factors that facilitate improvements in products and processes. If these factors arise from the activities of a firm, the original concept of upgrading is helpful. But, as Kaplinsky and Readman (2001) and Humphrey and Schmitz (2002) point out, this concept is restricted to the level of the firm and fails to capture upgrading processes across sectors. Also within sectors, upgrading processes that involve groups of interlinked firms in GVCs (due to the rise in international fragmentation) cannot be captured. Therefore, the interpretation of upgrading was widened by Kaplinsky and Readman (2001) and Humphrey and Schmitz (2002) who identified four distinct types of upgrading. These were process upgrading, product upgrading, functional upgrading, and inter-sectoral upgrading. Gereffi (2005) and Gibbon and Ponte (2005) attempted to catch these four types of upgrading in a single, more generic concept of upgrading. Upgrading is a move: to higher value-added activities in production; to the use of improved technology, knowledge and skills; and to increased benefits from participation in GVCs.

The four types of upgrading proposed by Kaplinsky and Readman (2001) and Humphrey and Schmitz (2002) were identified by them in a conceptual framework without quantitative measures. However, each of the four types of upgrading suggests its own indicators. Process upgrading refers to an increase in the efficiency of production processes. For example, the substitution of labor for capital (which happens when automation takes place) may yield a greater level of productivity. Indicators for process upgrading that have been proposed are labor productivity growth (Taglioni andWinkler, 2016), capital compensation growth (Milberg and Winkler, 2011), and capital intensity growth (Barrientos et al., 2011).

Product upgrading occurs where new products are introduced or when certain existing products are enhanced faster than are competing products. It entails moving into more sophisticated products within an existing value chain. Kaplinsky and Readman (2005) suggest the combination of the export growth and the growth in the export unit value (reflecting the average price of the exported products) are the indicators of product upgrading. Golley and Song (2011) provide further motivation for the use of the export unit value by arguing that product quality is the linchpin. Differences in product quality are globally evaluated by consumers and reflected in their preferences (and the shares) and consequently product prices. High quality products have higher prices than do low-quality products (Aiginger, 1997). A price increase thus reflects an upgrade of the quality of the product or service if the share is stable or rising.

Functional upgrading involves performing more sophisticated business functions or more skill-intensive activities. A typical example of functional upgrading is a move from simple assembly to full-package production to developing an own product design. This is reflected by increasing shares of skill-intensive activities and the use of high-skilled workers. Two proposed indicators for functional upgrading are the increase in the skill intensity of the sector's employment and the increase in the skill intensity of the exports (Barrientos et al., 2011; Milberg and Winkler, 2011).

The fourth type of upgrading is inter-sectoral upgrading. It is the shift to a more technologically advanced production chain. This involves disintegrating processes into other industries and/or other value chains. Inter-sectoral upgrading is related to changing the production mix toward producing goods and services with a higher value added. The production (and employment and exports) of a country gradually shifts across sectors, from agriculture and natural resource extraction to light industries like textile, and subsequently toward more modern manufacturing and the service sectors (Lewis, 1954). So far, there is no unambiguous indicator to measure inter-sectoral upgrading. But some researchers (Lin and Yu, 2015) use the sectoral composition of gross domestic product (GDP) and the sectoral composition of exports to study inter-sectoral upgrading at country level.

In conclusion, based on extant literature, the following seven indicators of industrial upgrading are extracted: labor productivity growth; capital compensation growth; capital intensity growth; export growth; growth of export unit value; growth of the skill intensity of employment; and growth of high-skilled labor exports. Three out of the seven indicators suggested in the literature are based on gross exports. Increased international production fragmentation has led to enormous growth in the trade in intermediate products and to countries specializing in small parts of value chains. This was made possible by rapidly falling communication and transport costs over the past two decades implying that various stages of production can be performed in other regions and countries. In the past, a country performed the whole production process of a product and exported the product to compete with other countries in the global market. The value that the exporting country received was the price of the exported product, and it reflected the gains or benefits for that country. Due to globalization, today's products and services are made in global production networks (GPNs) or GVCs, rather than in a specific country (Timmer et al., 2013, 2015). A country imports raw materials and intermediate goods, adds one or more layers of value, and sells the resulting product to a foreign producer who adds the next layer(s). In today's situation, the price of an exported product is no longer the value that the exporting country receives for the product. Consequently, the value of gross exports (as recorded by customs data and reported in official trade statistics) goes to all the countries involved in the production stages and not only to the final exporter. To capture this new situation, it is suggested new indicators of industrial upgrading, as the use of domestic value added of a country that is embodied in all foreign final demands (also known as value-added exports), rather than the value of gross exports.

Concerns about the gap between the value of gross exports and the value-added exports have been expressed. Case studies of the Apple iPad and iPhone (Kraemer et al., 2011) reveal that the value added generated in China (which exports the final Apple products) is only 1.8% of their export value for China. Because Apple continues to keep its pre- and post-fabrication activities (such as product design, software development, product management, and marketing) in the USA, the USA remains the main beneficiary in value-added terms. Other case studies of the iPod and laptops (Dedrick et al., 2010) and the Nokia smartphone (Ali-Yrkkö et al., 2011) confirm that these pre- and post-fabrication activities generate much value added (Baldwin and Evenett, 2012). China's benefits from participating in Apple's GVCs are thus much smaller than the huge gross export values from China suggest. This is because China is involved only in the assembly part of the GVCs, which generates little value added. Koopman et al. (2012) and Chen et al. (2019) focus on the role of assembly activities in producing export products. Their results show that the value added in exports related to assembly activities is much lower than the value added in other exports and is far lower than otherwise suggested by the gross export values (Johnson and Noguera, 2012). This gap between the value of gross exports and the value-added exports is well recognized. The OECD and the World Trade Organization (WTO) have launched their 'Made in the World' initiative and proposed 'trade in value added'. This alternative approach for the measurement of world trade provides a better answer to certain questions (OECD, 2012).

When measuring industrial upgrading, however, to our knowledge, only a few recent studies have adopted value added-based indicators from a GVC perspective. In this paper, the conventional indicators are adjusted and the value of gross exports is replaced by the value-added exports (i.e. the value added created in one country to satisfy – directly and indirectly – final demand in another country). For example, the growth of the export is replaced by the growth of the value-added exports. In the same way export unit value growth is adjusted. With regard to the other four indicators that are not based on gross exports (i.e. labor productivity growth, capital compensation growth, capital intensity growth, and growth of the skill intensity of employment), their conventional definitions are followed.

A second feature of our study is that there is a split of labor according to skill types. High-, medium- and low-skilled labor are determined by the educational attainment of the workers. The focus, in particular, is on high-skilled labor. The reason is that high-skilled workers are supposed to be more able than medium- and low-skilled workers to make better products and/or to make them more efficiently. High-skilled workers also often specialize in higher value-added activities such as R&D, design and marketing activities, whereas low-skilled workers are often production or service workers who create less value. A rising share of high-skilled labor thus indicates that an industry has experienced upgrading. The growth in the share of high-skilled labor is a proxy for the increased skill intensity of employment. For example, the growth of the skill intensity of exports is measured by the growth in the high-skilled labor embodied in foreign final demand.

Note that among the above seven indicators, the three indicators that are based on gross exports are adjusted, while keeping the conventional definitions for the other four indicators. Implementing the GVC perspective outlined above and calculating the indicators at country and sector level requires a time series of global multi-regional input–output tables. The World Input–Output Database (WIOT 2016) contains these tables and it provides the necessary employment data for the three skill levels. It also provides capital compensation and capital stock data at the same sectoral level. Considering that price fluctuation might affect the results, the world input–output tables are used in the prices of previous years and data on capital stock, gross output, and value added at constant prices to calculate corresponding indicators.

Against this background of opening-up and industrial upgrading of China, this paper tries to investigate the relationship and the causality between economic opening-up and major determinants of industrial upgrading in a GVC framework. The paper is outlined as follows. Next section outlines the research methodology and describes the data used in this study. Section 3 gives and discusses the results of wavelet analysis and granger causality results; and in the final section concluding remarks are presented.

2. METHODOLOGY

2.1 Selection of Variables

What is the impact of economic opening-up on industrial upgrading? How is economic opening-up related to product and process upgrading? What is actually known about the nexus between the economic opening-up and skill upgrading? Responding to these emerging queries, with some fresh new insights from China is the primary objective of this paper. For this purpose, the indicators for measuring economic opening-up are described in this section. Further, industrial upgrading in GVC for China and its indicators are also elaborated under three main dimensions i.e. product, process and skill upgrading.

2.1.1 Economic Opening-up

The measurement of a country's economic opening up should at least include trade openness and investment openness, trade openness involves import dependency and export dependency, and investment openness involves foreign direct investment (FDI) dependency and outward foreign direct investment (OFDI) dependency. This paper measures the dependence of import, export, FDI, and OFDI by the proportion of above four items in GDP of each province. This paper uses factor analysis method to measure the comprehensive economic opening up of China from above four aspects (Su and Liang, 2021). The total amount of import and export, foreign direct investment and outward foreign direct investment are converted into RMB yuan using the intermediate price of RMB yuan against the US dollar in the current year (Su and Liang, 2021).

2.1.2 Industrial Upgrading in GVC

Table 1: The World Multi-Regional Input-Output Table

	Intermediate Use					Final Use					Total Output
	$in\ 1$	$\cdots$	$in\ r$	$\cdots$	$in\ n$	$in\ 1$	$\cdots$	$in\ r$	$\cdots$	$in\ n$	
$Country\ 1$	Z^{11}	$\cdots$	Z^{1r}	$\cdots$	Z^{1n}	f^{11}	$\cdots$	f^{1r}	$\cdots$	f^{1n}	x^1
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$⋰$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$⋰$	$\vdots$	$\vdots$
$Country\ r$	Z^{r1}	$\cdots$	Z^{rr}	$\cdots$	Z^{rn}	f^{r1}	$\cdots$	f^{rr}	$\cdots$	f^{rn}	x^r
$\vdots$	$\vdots$	$⋰$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$⋰$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
$Country\ n$	Z^{n1}	$\cdots$	Z^{nr}	$\cdots$	Z^{nn}	f^{n1}	$\cdots$	f^{nr}	$\cdots$	f^{nn}	x^n
Value addition	$(v^1)'$	$\cdots$	$(v^r)'$	$\cdots$	$(v^n)'$						
Total Inputs	$(x^1)'$	$\cdots$	$(x^r)'$	$\cdots$	$(x^n)'$						

Source: Modified from Tian et al. (2019)

Based on the work of Tian et al. (2019), the starting-point for calculation of industrial upgrading in GVC is the world multi-regional IO table in Table 1 with n countries and m sectors (or industries) in each country. The $m \times m$ matrix Z^{sr} gives intermediate deliveries from country s to country r. Its typical element z_{ij}^{sr} gives the value of goods and services shipped from sector i in country s for intermediate use by sector j in country r. The value of goods and services shipped from sector i in country s to country r for final use (household consumption, private investments, and government expenditures) is given by f_i^{sr} , the typical element of the vector f^{sr}. The value of the output by sector i in country s is given by x_i^s , the typical element of the vector x^s. The accounting identity (or product market clearing condition) is:

$$x_i^s = \sum_j \sum_r z_{ij}^{sr} + \sum_r f_i^{sr} \ldots (1)$$

If the u is used to indicate the m-element summation vector consisting entirely of ones, then the accounting identities can be written in the matrix form as:

$$\begin{bmatrix} x^1 \\ \vdots \\ x^r \\ \vdots \\ x^n \end{bmatrix} = \begin{bmatrix} Z^{11} & \cdots & Z^{1r} & \cdots & Z^{1n} \\ \vdots & \ddots & \vdots & ⋰ & \vdots \\ Z^{r1} & \cdots & Z^{rr} & \cdots & Z^{rn} \\ \vdots & ⋰ & \vdots & \ddots & \vdots \\ Z^{n1} & \cdots & Z^{nr} & \cdots & Z^{nn} \end{bmatrix} \begin{bmatrix} u \\ \vdots \\ u \\ \vdots \\ u \end{bmatrix} + \begin{bmatrix} \sum_t f^{1t} \\ \vdots \\ \sum_t f^{rt} \\ \vdots \\ \sum_t f^{nt} \end{bmatrix} \quad \ldots (2)$$

The $m \times m$ matrix $A^{sr} = Z^{sr}(\hat{x}^r)^{-1}$ gives the input coefficients. Its typical element $a_{ij}^{sr} = z_{ij}^{sr}/x_j^r$ gives the dollars of input from sector i in country s for intermediate use by (and measured per dollar of output by) sector j in country r. This yields:

$$\begin{bmatrix} x^1 \\ \vdots \\ x^r \\ \vdots \\ x^n \end{bmatrix} = \begin{bmatrix} A^{11} & \cdots & A^{1r} & \cdots & A^{1n} \\ \vdots & \ddots & \vdots & ⋰ & \vdots \\ A^{r1} & \cdots & A^{rr} & \cdots & A^{rn} \\ \vdots & ⋰ & \vdots & \ddots & \vdots \\ A^{n1} & \cdots & A^{nr} & \cdots & A^{nn} \end{bmatrix} \begin{bmatrix} x^1 \\ \vdots \\ x^r \\ \vdots \\ x^n \end{bmatrix} + \begin{bmatrix} \sum_t f^{1t} \\ \vdots \\ \sum_t f^{rt} \\ \vdots \\ \sum_t f^{nt} \end{bmatrix} \quad \ldots (3)$$

Let the final demands vector be split into n vectors, one for each receiving country. That is, define:

$$f = \begin{bmatrix} \sum_t f^{1t} \\ \vdots \\ \sum_t f^{rt} \\ \vdots \\ \sum_t f^{nt} \end{bmatrix} = \begin{bmatrix} f^{11} \\ \vdots \\ f^{r1} \\ \vdots \\ f^{n1} \end{bmatrix} + \cdots + \begin{bmatrix} f^{1n} \\ \vdots \\ f^{rn} \\ \vdots \\ f^{nn} \end{bmatrix} = f^1 + \cdots + f^n \ldots (4)$$

Equation 3 can be written as $x = Ax + f = Ax + (f^1 + \cdots + f^n)$ and the solution is given by $x = (I - A)^{-1}(f^1 + \cdots + f^n) = L(f^1 + \cdots + f^n)$, where $L = (I - A)^{-1}$ is the Leontief inverse. In its partitioned form this $nm \times nm$ matrix is given by:

$$L = \begin{bmatrix} L^{11} & \cdots & L^{1r} & \cdots & L^{1n} \\ \vdots & \ddots & \vdots & ⋰ & \vdots \\ L^{r1} & \cdots & L^{rr} & \cdots & L^{rn} \\ \vdots & ⋰ & \vdots & \ddots & \vdots \\ L^{n1} & \cdots & L^{nr} & \cdots & L^{nn} \end{bmatrix} \ldots (5)$$

The outputs that are necessary for (or embodied in) the final demands of any country except country s are given by $L(\sum_{t \neq s} f^t)$ .Note that for country s the nm-element vector $\sum_{t \neq s} f^t$ gives foreign final demands. The domestic output embodied in the foreign final demands is, for country s, given by $\sum_k L^{sk}(\sum_{t \neq s} f^{kt})$.

The m-element vector $(v^r)' = (w^r)'(\hat{x}^r)^{-1}$ gives the value-added coefficients in country r. Its typical element $v_j^r = w_j^r / x_j^r$ gives the value added (in dollars) generated in sector j in country r per dollar of output in this sector. The value added generated in sector i in country s that is embodied in foreign final demands (i.e. final demand outside country s) is given by the ith element of the vector

$$VAX^s = \sum \sum \hat{v}^s L^{sk} f^{kt} \ldots (6)$$

This is value added of country s that ultimately ends up in a foreign final demand bundle (e.g. consumption of households abroad). This is the export by country s of its domestic value added. The value-added exports of country s (VAX^s) and the value-added exports of sector i in country s are given by $VAX^s = u'VAX^s$.

The next section continues with presenting and defining the upgrading indicators under three dimensions i.e. product, process and skill upgrading.

2.1.2.1 Product Upgrading

The indicators of product upgrading are growth of value-added exports and unit value-added exports. These indicators are described as follow:

Growth of value-added exports (VAX_g): The value-added exports are calculated in equation (6).

Growth of the unit value-added exports (VAXR_g): The unit value-added exports are also known as the VAX-ratio (Johnson and Noguera, 2012). It is calculated as the value-added exports (of a country or industry) divided by the gross exports.

2.1.2.2 Process Upgrading

The indicators of process upgrading are growth of labor productivity, capital compensation and capital intensity. These indicators are described as follow:

Labor productivity growth (LP_g): Labor productivity is calculated as the ratio of value added to labor, i.e. the value added per unit of labor. Labor is defined as ‘all persons engaged’. This includes, next to all paid employees, also the self-employed and informal workers. Note that this indicator (and all indicators hereafter) is a growth rate. That is, $LP\_g = (lp_t - lp_t - 1)/lp_t - 1$, where lp_t denotes the labor productivity of a country in year t.

Capital compensation growth (CC_g): Capital is one of the three primary factors of production (i.e. natural resources, labor, and capital), consisting of both tangible (like machinery and buildings) and intangible assets (like patents and copyrights). Capital compensation refers to the remuneration for the use of capital assets.

Capital intensity growth (CI_g): Capital intensity is calculated as the ratio of capital stock to labor. The capital stock is the value of the fixed capital that can be used as input in production of goods and services in an accounting interval. Capital stocks have been constructed on the basis of the Perpetual Inventory Method in which the capital stock in year t is estimated as the sum of the depreciated capital stock in year $t - 1$ plus real investment in year t.

2.1.2.3 Skill Upgrading

The indicators representing the skill upgrading are growth of skill intensity of employment and high skilled-labor exports. These can be calculated as follow:

Growth of the skill intensity of employment (SKE_g): The skill intensity of employment is obtained as the amount of high-skilled labor (measured in working hours) as a share of total employment. The labor force in each industry distinguishes low-skilled, medium-skilled, and high-skilled workers.

Growth of high-skilled labor exports (HSLE_g): It is calculated as the amount of high-skilled labor (also measured in working hours) that is directly and indirectly needed in the production for foreign final demand. Time paths for all the variables are portrayed in Figures 1-3.

Figure 1: Time paths of Indicators of Product Upgrading from 2001-2014

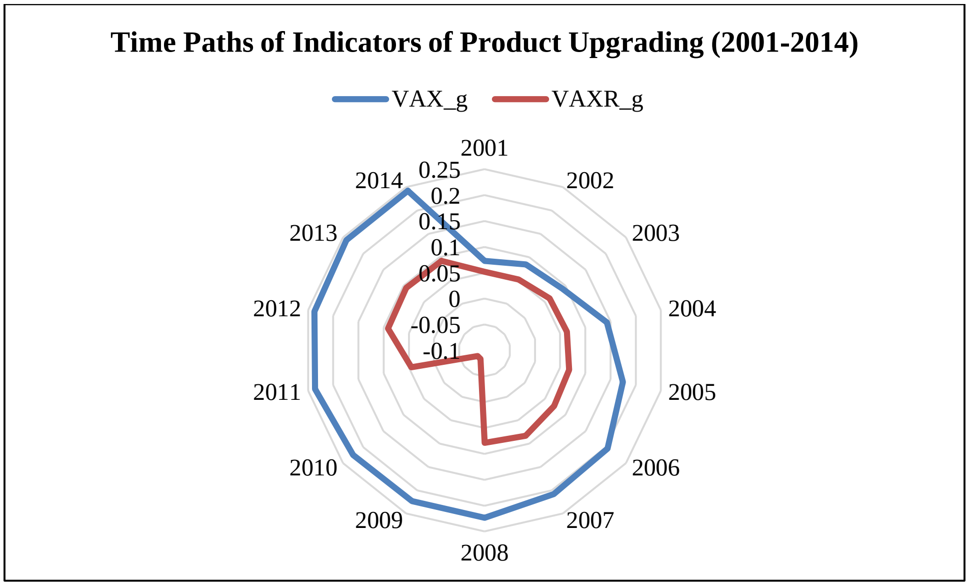


Figure 2: Time paths of Indicators of Process Upgrading from 2001-2014

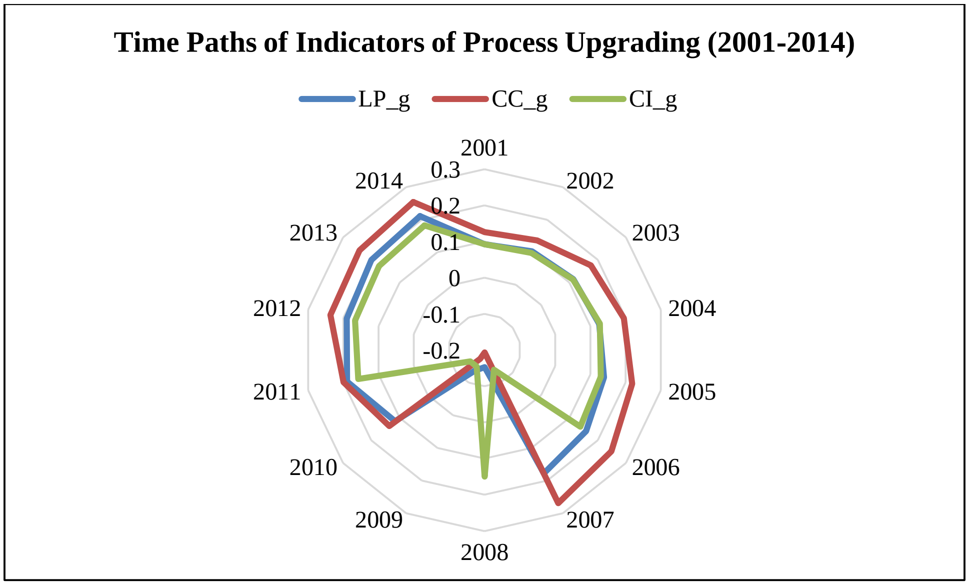
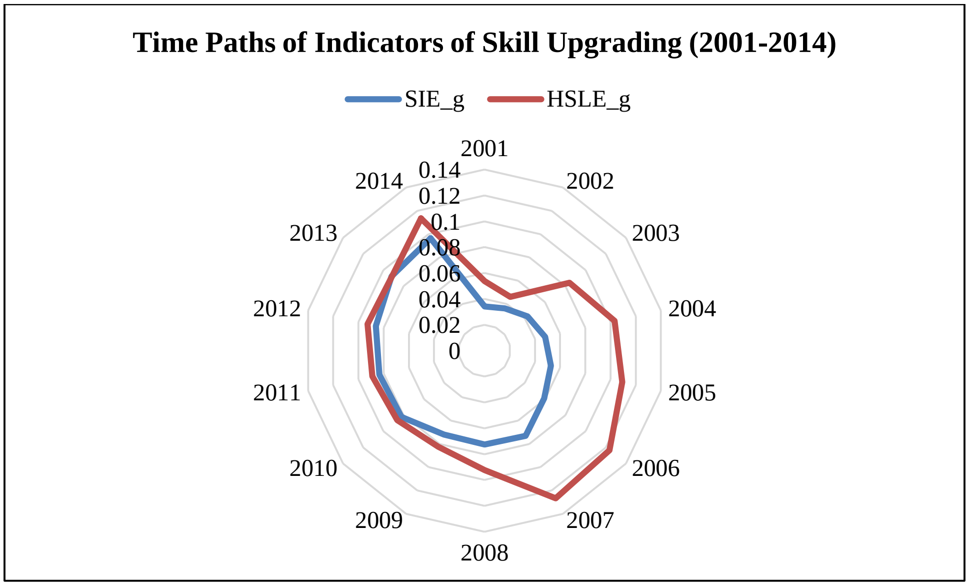


Figure 3: Time paths of Indicators of Skill Upgrading from 2001-2014



2.2 Data Sources

The data employed in current study consists of yearly observations (time series data from 2001 to 2014) for all the indicators discussed in previous section. Main data sources include National Statistical Yearbooks of China and World Input-Output Database (WIOT 2016 Release).

2.3 Empirical Analysis

Our main purpose is to examine the link between economic opening-up and indicators of product, process and skill upgrading of China, by deploying wavelet transform context structures. Moreover, in current study, the correlation analysis, wavelet coherency and wavelet-based Granger causality analysis are employed to develop the nexus between economic opening-up and indicators of industrial upgrading in a GVC scenario, by using time series data of yearly frequency from 2001 to 2014, and taking growth rates of all the data series for better results of wavelet analysis.

2.3.1 Pearson correlation

For selection of correlation test, it was checked that either our data is normally distributed or not, by employing Kolmogorov-Smirnov Z test. The results of Kolmogorov-Smirnov Z test indicate that data for all variables is normally distributed, thus lead us to the use of Pearson correlation analysis, as normality of data is the prerequisite for such analysis. The formula for Pearson correlation coefficient (r) for two variables x and y, as developed by Pearson (1895) and quoted by Dănăcică (2017), is as follow:

$$r_{y/x} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})/[\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2]^{1/2} \dots (7)$$

2.3.2 Wavelet coherency

In current study, the WTC was employed, as a much better technique, to investigate the co-movement of economic opening-up and selected variables of industrial upgrading of China, through a graphical output. This innovative econometric technique is used by many researchers for economic relationships (Abdessalem and Benammou, 2018; Das and Kumar, 2018; Gallegati, 2008; Raza et al. 2018; Singh et al. 2019; Wu and Wu, 2019), as it is based on decomposition of time-series (at different time frequencies), and provides a three-dimensional analysis. In current study, following the method of Torrence and Compo (1998), following equation for wavelet coherence is used:

$$W^2{}_{xy^{(p,q)}} = \frac{\left|S(S^{-1}N_{xy}(p,q)\right|^2}{S(S^{-1}|N_x(p,q)|^2)\,S(S^{-1}\left|N_y(p,q)\right|^2)} \quad \ldots (8)$$

Where

S = Smoothing mechanism

$N_x(p,q)$ = continuous transform of variable x (t)

$N_y(p,q)$ = continuous transform of variable y (t)

p = location index

q = measure

Further, range of squared coefficient of wavelet coherence is depicted by $0 \leq W_{xy}^2\,(p,q) \leq 1$. For detailed mathematical derivations, Torrence and Compo (1998) can be referred as a base source for interested readers.

2.3.3 Granger Causality Analysis

Wavelet based Granger causality analysis was employed up to six frequency domains (D1 to D6), as suggested by Sharif et al. (2020), with the purpose of testing for Granger causality between variables in a bivariate model, and thus checking for robustness of wavelet coherence results. Further, the possibility of Granger causality between all product, process and skill upgrading' parameters during economic opening-up of China is checked by this approach.

3. RESULTS AND DISCUSSION

3.1 Pearson Correlation Analysis

The results of Kolmogorov-Smirnov Z Coefficient (KSC) indicate the normality of data, thus leading to the selection of Pearson correlation analysis. Mean values for LP_g, CC_g, CI_g, VAX_g, VAXR_g, SIE_g, HSLE_g, and EOU are 0.1091, 0.1479, 0.0779, 0.1864, 0.0492, 0.0665, 0.0925, and 0.0064, respectively (Table 2).

Table 2: Descriptive statistics

Variables	N	Mean	Standard Deviation	KSC Value	Critical Value at 99 % CI
LP_g	14	0.1091	0.1141	0.9250	1.94947
CC_g	14	0.1479	0.1477	0.8305	1.94947
CI_g	14	0.0779	0.1243	0.2396	1.94947
VAX_g	14	0.1864	0.0623	0.9587	1.94947
$VAXR\_g$	14	0.0492	0.0577	0.9677	1.94947
SIE_g	14	0.0665	0.0209	0.8831	1.94947
$HSLE\_g$	14	0.0925	0.0229	0.9750	1.94947
EOU	14	0.0064	0.1064	0.9272	1.94947

Source: Author's own calculation

The results of Pearson correlation analysis of all variables with EOU are presented in Table 3. The value of Pearson Coefficient (PC) indicates the significant positive correlation between EOU and LP_g, CC_g, CI_g, VAXR_g and HSLE_g. Further, a negative correlation was found between EOU and VAX_g and SIE_g, all of these results are statistically significant. Thus, it is indicated all the studied indicators of product, process and skill upgrading are related and affected by the economic opening up of China.

Table 3: Pearson correlation analysis of all variables with economic opening up

Variables	PC value	t-stat	p-value
LP_g	0.3437	4.327679	$2.48E^{-05}$
CC_g	0.3894	8.104444	$1.48E^{-13}$
CI_g	0.1425	35.42191	$1.26E^{-75}$
VAX_g	-0.1475	2.158943	0.032393
$VAXR\_g$	0.2184	7.320449	$1.14E^{-11}$
SIE_g	-0.1831	3.172445	0.001823
$HSLE\_g$	0.1627	15.00232	$5.36E^{-32}$

Source: Author's own calculation

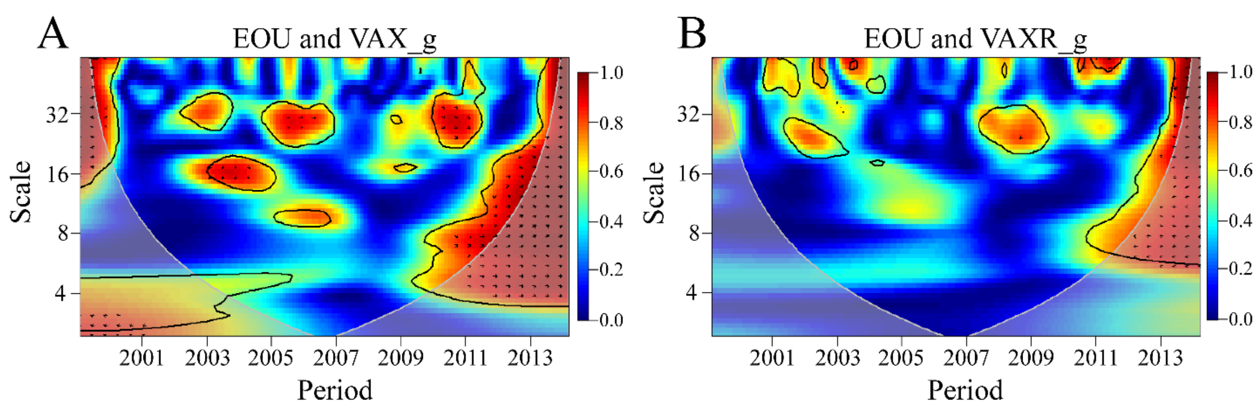
3.2 Wavelet Coherence:

The opening-up policy is believed to have had an important effect on economic growth in many developing countries, especially China (Ma et al., 2010). For analyzing the interaction between EOU and indicators of China's industrial upgrading in GVC, wavelet coherence plots (WCP) for all pair of variables are shown in Fig 4-7. In a typical WCP, the colors highlighted inside the cone of influence (the area separating significant region from the rest) depict the strength of relationship between two variables in a bivariate model. The strength of correlation moves from strong to weak, as moving from red to blue color. Further, 5% significance is exhibited by a black contour around a color (specifically around red, yellow color, and to some extent, around light green color).

As far as impact of economic opening up on product upgrading is concerned, the impact of EOU on growth of value added exports is of great importance. The plot between economic opening up and growth of value added exports exhibit huge red islands for the whole sample period and for all short, medium and long run periods (Figure 4A). Figure 4B plots the coherence between economic opening up and growth of the unit value-added exports. A strong coherence can be seen between these two variables in the long run (16-32 days' frequency bands), typically at the start and middle of the sample period. Moreover, strong island of red color at the end of sample period show strong and significant dependence of unit value-added exports on economic opening up of China.

The theoretical link between economic opening up and economic growth has been well documented in the literature (Perera-Tallo, 2003). Trade openness promotes value added exports, since it enhances specialization and division of labor in production (Sakyi et al., 2015). This contributes to a more efficient allocation of domestic resources and to improve productivity as much as the trade potential of the economy. Moreover, intensifying the integration of FDI and export related initiatives are therefore the sure way to enhance value added exports, and thus product upgrading. FDI may raise firms' markups through positive technology spillovers. It may also lower the relative price of domestic intermediate inputs by expanding the market demand for upstream suppliers and providing technological support to upstream firms, thus leading to increase in value addition (Lu et al., 2022). It is therefore recommended that the channeling of FDI into areas of comparative advantage (such as export-oriented industrial, agricultural and other productive sectors of the economy) be intensified if the nation is to wholly harness the benefits of FDI activities. A clear manifestation of government's commitment to this initiative is therefore crucial in this effort (Sakyi et al., 2015).

Figure 4: Pairwise Estimates of Wavelet Coherence between Economic Opening-up and Growth of Value-Added Exports (A), Economic Opening-up and Growth of the Unit Value-Added Exports (B)



As portrayed in Figure 5A, over both short (4-8 days frequency bands) and long run (16-32 days' frequency bands) period, there exists a mild and strong coherence respectively, between economic opening-up and growth of labor productivity, with the later one having coherence at the beginning and middle of sample period. These results unravel that a country's opening-up also pose effects on labor productivity, thus raising concerns of policy makers. Hitherto, the effect of increasing trade openness was also found significant on labor productivity (Vukšić, 2016). Furthermore, countries with higher levels of trade openness display essential productivity gains (Kacou et al., 2022). The China's opening up process accompanies capital deepening, which is highly correlated with labor savings, which ultimately levies the largest influence on the labor productivity (Yang and Lahr, 2010).

The wavelet coherence plot between economic opening-up and growth of capital compensation is plotted in Figure 5B. A strong coherence can be seen between these two variables in the long run (16-32 days' frequency bands), typically at the start and middle of the sample period, with strong island of red color at the end of sample period. This indicates strong and significant dependence of capital compensation on EOU. This finding is in line with extant literature in the light of compensation hypothesis (Aregbeyen and Ibrahim, 2014). As per compensation hypothesis, a central assumption in the globalization literature is that economic openness generates economic insecurity and volatility, which then bolsters the welfare state by increasing public demand for social protection against externally generated economic instability (Kim, 2007). Finally, the connectedness between EOU and growth of capital intensity is significant during medium and long run, and for the start and mid of sample period, as shown by red zones of coherence in Fig. 6C. Meanwhile, the downward right direction of arrows gives the perception of strong causality from economic opening-up to capital intensity, thus suggesting significant effects of opening-up on process upgrading of China. A country with abundant capital can expand its capital-intensive sectors and export their goods along with trade liberalization (Setyari et al., 2016). By emphasizing global competitiveness, opening up may encourage growth of capital intensity in the manufacturing sector as a whole (Ghose, 2000). Moreover, opening-up, in foreign direct investment (FDI) and trade, is often seen as an important catalyst for economic growth in the developing countries (Makki & Somwaru, 2004). Therefore, for developing the economy through process upgrading, strengthened collaboration on policy measures by fiscal and regulatory authorities is of dire need.

Figure 5: Pairwise Estimates of Wavelet Coherence between Economic Opening-up and Labor Productivity Growth (A), Economic Opening-up and Capital Compensation Growth (B), Economic Opening-up and Capital Intensity Growth (C)

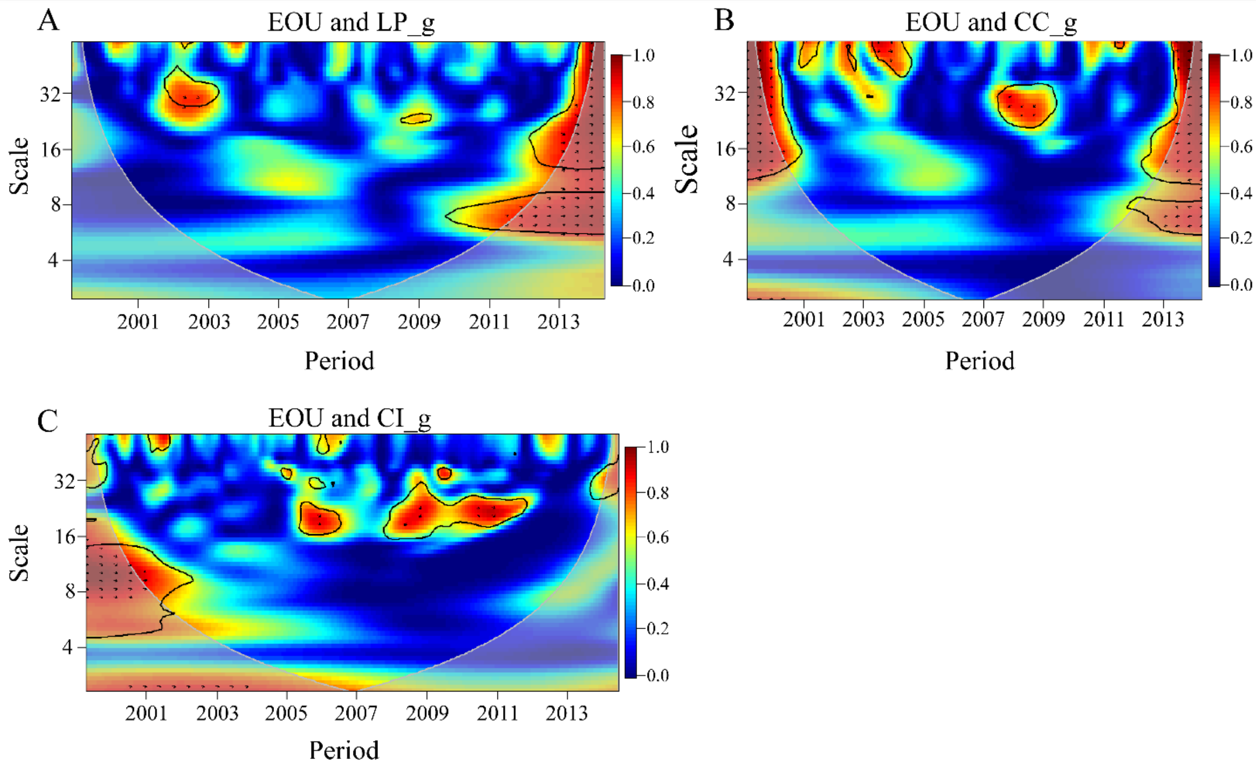
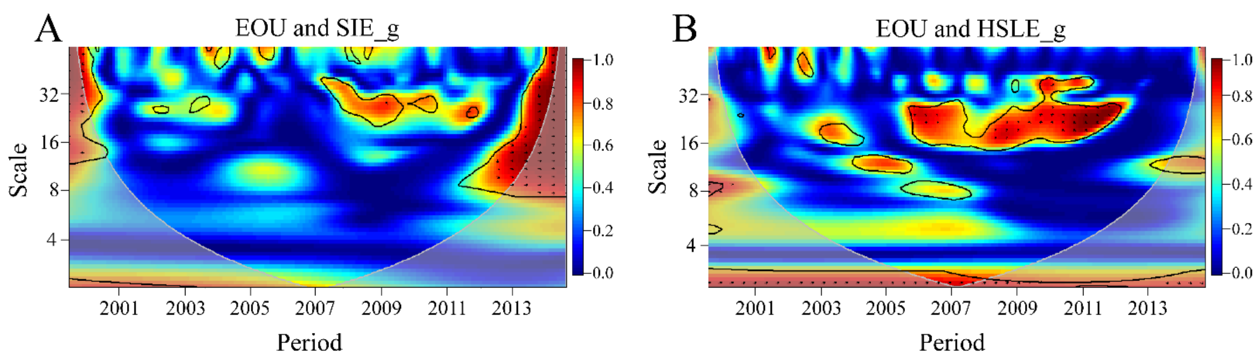


Figure 6: Pairwise Estimates of Wavelet Coherence between Economic Opening-up and Growth of the Skill Intensity of Employment (A), Economic Opening-up and Growth of High-Skilled Labor Exports (B)



The skill upgrading of Chinese economy seems to be responsive to escalating opening-up of the country. The wavelet coherence between economic opening-up and indicators of skill upgrading is shown in Figure 6 (A and B). In the coherence plot between EOU and growth of skill intensity of employment, red islands of high dependence can be visualized for long run period (16-32 days frequency bands) at both the start and end of sample period, with the arrows mostly pointed down and right, thus implying the direction of causality from EOU to skill intensity of employment. Further, small islands of mild coherence, significant at some points, also exist throughout the sample period. As for the dependency between EOU and growth of high skilled labor exports is concerned, Fig. 6B clearly presents the existence of hot red zones during medium and long run, mostly for the middle of the sample period. While referring to the arrows, their upward and both right and left direction indicates that both variables are leading each other for some time, thus the tremendous increasing trend of economic opening-up of China greatly affected high skilled labor exports of the country. According to Ghose (2000), across industries, output per worker rises as the ratio of skilled to unskilled workers employed in production rises, thus workers working with more and better machines produce more, but they also need to be more skilled if they are to work with more and better machines. Moreover, on the whole, growth of manufactured exports to industrialized countries increases demand for skilled workers in developing countries (Ghose, 2000).

Figure 7: Pairwise Estimates of Wavelet Coherence between Economic Opening-up and Product Upgrading (A), Economic Opening-up and Process Upgrading (B), Economic Opening-up and Skill Upgrading (C)

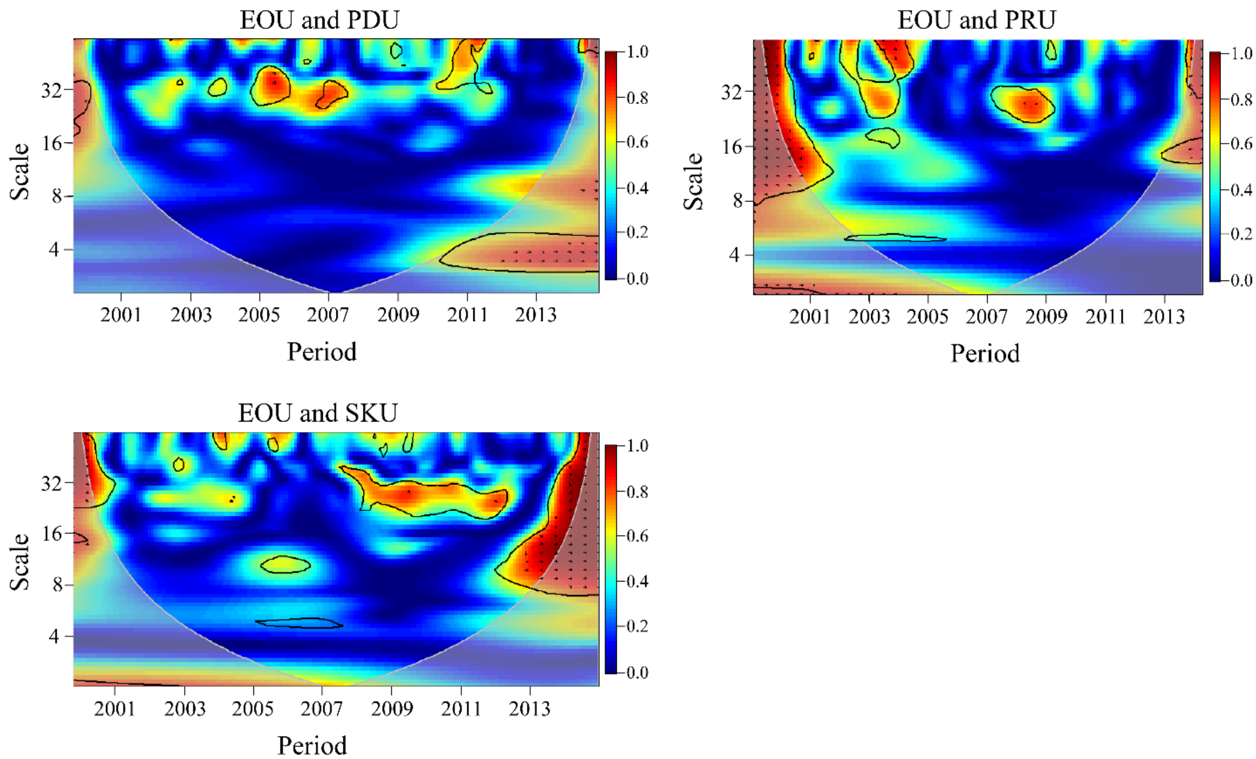


Figure 7 portrays wavelet coherence between economic opening-up and product, process and skill upgrading of China. In case of product upgrading, small hot red zones can be clearly seen, specifically in the long run and throughout the sample range (Figure 7A), and the visual inspection of these islands unravels that arrows are directed mostly towards up and right. New growth theory posits that openness mainly elevates upgrading through accelerating technical progress and boosting factor productivity (Kong et al., 2021), thus causing a direct contribution in product upgrading. Further, a strong coherence can be seen between EOU and process upgrading in the long run (16-32 days' frequency bands), typically at the start and middle of the sample period (Figure 7B). Hitherto, it is proved that there exist a positive and powerful complementary relationship between trade openness and capital formation (Kehu and Wang, 2017), which ultimately leads to process upgrading. On the other hand, the skill upgrading is in significant coherence with EOU over two frequency bands (8-16 days and 16-32 days) for the entire sample period, depicting both medium and long run relationship between economic opening-up and skill upgrading in China (Figure 7C). At the end of sample period, strong island of red color show strong and significant dependence of skill upgrading on EOU, with the arrows predominantly pointing towards down and right, thus indicating the direction of causality from EOU towards skill upgrading at the end of sample period. Wang et al. (2019) have contended that trade openness improves capacity utilization and output levels significantly by expanding the market size, as well as significantly influencing capital deepening and driving economic growth by changing the skill of the labor force.

3.3 Granger Causality Analysis

Table 4 portrays the results of granger causality test. As shown in Table 4, at 1% significance level, fluctuations in economic opening-up do not Granger-cause labor productivity growth, capital intensity growth, and unit value-added exports' growth. But it is worth noting that EOU does Granger-cause growth of high skilled labor exports (1%) for all frequency domains; capital compensation growth (1% significance level for D4 and 5% for all remaining frequencies); value-added exports' growth (5% significance level) for all frequency domains; and growth of skill intensity of employment (10% significance level) for D1 frequency domain only. These results suggest that the economic opening-up of a country like China may pose significant short and long run impact on product, process and skill upgrading. The results are in line with existing literature studying the economic impact of opening-up (Chen and Yang, 2010; Su and Liang, 2021).

Table 4: Results of Granger-Causality Test

f	Dependent Variable	Independent Variables (Signif. codes: '***' 0.01 '**' 0.05 '*' 0.1)(F Pr(>F))							
		C	LP_g	CC_g	CI_g	VAX_g	$VAXR\_g$	SIE_g	$HSLE\_g$
D1	C	-	2.84*	2.41	0.68	0.81	0.53)	0.18	0.00
	LP_g	0.09	-	4.01**	0.28	2.79*	0.63	0.00	4.35**
	CC_g	3.32**	0.41	-	0.53	0.49	0.08	0.04	0.42
	CI_g	0.00	1.71	4.62**	-	4.19**	2.79*	0.00	1.64
	VAX_g	0.01**	0.22	0.00	1.14	-	0.01	1.14	0.79
	$VAXR\_g$	0.99	2.86*	0.13	0.68	0.49	-	0.76	0.22
	SIE_g	2.78*	0.17	0.17	0.50	1.61	0.61	-	0.02
	$HSLE\_g$	0.41***	0.01	0.86	0.32	0.02	1.46	0.49	-
D2	C	-	2.60*	1.59	0.42	0.55	0.11	2.57*	0.34
	LP_g	0.90	-	2.07	0.90	1.39	0.70	0.23	2.44
	CC_g	2.14**	3.06**	-	0.67	0.31	0.10	0.08	0.61
	CI_g	0.11	1.49	2.62*	-	2.62*	1.08	0.21	1.59
	VAX_g	0.27**	2.46*	0.17	1.52	-	0.77	2.29*	1.76
	$VAXR\_g$	0.47	1.39	0.30	0.38	0.29	-	0.62	3.83**
	SIE_g	1.16	0.72	0.16	0.34	3.11**	0.63	-	0.29
	$HSLE\_g$	3.71***	0.45	0.41	2.48*	0.13	1.07	0.38	-
D3	C	-	4.50***	1.98	0.48	0.54	1.08	4.80***	0.14
	LP_g	1.17	-	1.72	0.83	3.04**	0.73	0.31	2.15*
	CC_g	1.72**	2.23*	-	0.49	1.01	0.14	0.09	1.47
	CI_g	0.26	1.02	2.49*	-	1.65	0.76	0.76	1.75
	VAX_g	0.48**	2.26*	0.12	1.54	-	0.82	1.56	2.50*
	$VAXR\_g$	0.55	0.96	0.22	0.28	0.62	-	2.39*	2.63**
	SIE_g	1.40	1.21	0.19	0.20	3.19**	1.22	-	2.83**
	$HSLE\_g$	7.32***	0.34	1.58	1.40	2.41*	1.94	0.09	-
D4	C	-	4.93***	1.38	0.49	0.37	1.84	4.52***	0.21
	LP_g	2.05	-	1.36	1.35	2.56**	0.41	0.80	1.71
	CC_g	1.38***	1.59	-	0.65	0.77	0.40	0.10	2.00*
	CI_g	0.17	1.37	1.86	-	1.21	0.55	0.63	1.19
	VAX_g	0.49**	1.98	0.17	1.38	-	1.05	1.04	2.34*
	$VAXR\_g$	0.86	1.19	0.23	0.21	0.98	-	2.24*	2.74**
	SIE_g	1.08	1.05	0.15	0.34	2.81**	1.04	-	2.45**
	$HSLE\_g$	6.73***	1.89	3.12**	0.97	2.17*	1.75	0.74	-
D5	C	-	4.00***	1.29	0.41	0.36	2.83**	4.37***	0.64
	LP_g	1.98*	-	1.12	1.16	2.48**	0.29	0.82	1.38
	CC_g	1.35**	1.31	-	0.65	0.57	0.71	0.06	2.08*
	CI_g	0.21	1.21	1.70	-	1.48	0.43	0.75	1.03
	VAX_g	0.66**	2.21*	1.25	3.48***	-	0.89	1.67	2.17*
	$VAXR\_g$	1.93*	1.92*	0.22	0.26	0.91	-	1.54	2.24*
	SIE_g	0.66	0.92	0.15	0.33	2.98**	0.92	-	3.98***
	$HSLE\_g$	6.09***	2.10*	3.43***	1.20	2.24*	1.32	0.60	-
D6	C	-	4.47***	1.37	0.49	0.81	2.83**	5.49***	0.95
	LP_g	2.07*	-	1.68	1.18	1.85*	0.35	0.74	1.11
	CC_g	1.29**	1.10	-	0.57	0.77	0.93	0.08	1.52
	CI_g	0.25	1.03	1.41	-	1.20	0.47	0.74	0.83
	VAX_g	0.69**	2.22**	1.09	2.93**	-	0.78	2.21**	2.70**
	$VAXR\_g$	1.59*	1.97*	0.21	0.45	0.84	-	1.45	2.23**

	SIE_g	0.64	1.06	0.24	0.82	3.39***	2.51**	-	3.73***
	$HSLE\_g$	5.61***	9.79***	2.88**	1.22	1.73	1.05	0.57	-

Source: Author's own calculation

4. CONCLUSION

The aim of this study is to analyze the time-frequency connectedness between economic opening-up of China and indicators of industrial upgrading in GVC. For policy makers, individual firms and all industry participants, the impact of economic opening-up on industrial economy is crucial. Moving towards the impact of opening-up on industrial upgrading, following questions arise. What is the impact of economic opening-up on industrial upgrading? How is economic opening-up related to product and process upgrading? What is actually know about the nexus between the economic opening-up and skill upgrading? Responding to these emerging queries, with some fresh new insights from China is the primary objective of our research on the connectedness between economic opening-up of China and indicators of industrial upgrading in GVC. The study was conducted within a time-frequency domain, by employing yearly data from 2001 to 2014 and wavelet approach. Economic opening-up was calculated using the trade openness and investment openness, while industrial upgrading in GVC was indicated by product, process and skill upgrading. Correlation analysis, wavelet coherence plots and granger-causality analysis are the analytical tools applied for empirical investigation. The results show strong noises of red color between economic opening-up and indicators of product, process and skill upgrading. The results of granger causality analysis suggest that the economic opening-up of a country like China may pose significant short and long run impact on product, process and skill upgrading. Thus, it is concluded that product, process and skill upgrading of China are responsive towards its economic opening-up. Moreover, our analysis contributes to growing research and work on economic opening-up and its economic implications, as well as current policy concerns regarding industrial upgrading in the global value chain. Future studies could extend our study, by incorporating advance econometric techniques to explain the reaction of indicators of industrial upgrading towards opening-up of a country.

Declarations

Competing interests

No competing interests have been declared by authors.

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