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EDITED BY
Shuhong Wang,
Shandong University of Finance and Economics, China

REVIEWED BY
Yuanxiang Zhou,
Anhui University of Finance and Economics, China
Zhibo Zhao,
Qilu University of Technology, China
Xiaoqing Wang,
Ocean University of China, China

*CORRESPONDENCE
Huiqun Liu,
huiqunliu@tjcu.edu.cn

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# Does environmental regulation affect global value chain position in service sectors? Evidence from 41 major economies

Huiqun Liu*, Lixin Chen and Yibing Shan

Department of International Economics and Trade, School of Economics, Tianjin University of Commerce, Tianjin, China

The increasing international division of production and stringent environmental policies coexist, which lets people focus more on the research on the relationship between environmental regulation and the global value chain (GVC). Based on the characteristics of service sectors, this study proposes hypotheses of how environmental regulation affects GVC position in service sectors and empirically investigates it by using panel data of the GVC position index in service sectors and the environmental performance index (EPI) from selected 41 major economies during 2006–2014. Our empirical study found the following: first, environmental regulation has significantly promoted the increase of GVC position in service sectors, which obviously can verify the validity of the Porter hypothesis. Second, environmental health has a greater effect on GVC position in service sectors than on ecosystem vitality. Third, the influence of environmental regulation on GVC position in service sectors is heterogeneous under different quantiles. The higher per capita income, the more stringent their environmental regulation and the stronger their impact on GVC position in service sectors. In general, this study will contribute to a better understanding of the relationship between environmental regulation and GVC.

KEYWORDS

**global value chain, environmental regulation, service sectors, environmental performance index, environmental policies**

## 1 Introduction

Over the past 3 decades, the trend of dividing production into multiple specialized links in order to exploit the different comparative advantages in factor endowments and efficiencies across countries is becoming more and more obvious. With the rise of the global production networks, a global value chain (GVC) has been gradually formed. In the era of the GVC, which has dramatically changed the patterns of production and trade across countries, the offshoring production is becoming more and more popular. Countries undertake upstream or downstream activities in the GVC according to their comparative advantage and thus get different profit gains (Hummels et al., 2001; Antras et al., 2012). Specifically, upstream activities such as design and research and development (R&D) are always involved with high value-added, high-tech, and low-

carbon production links, where countries can get substantial profits. In contrast, downstream activities of the GVC, such as raw materials and intermediate inputs, are always related with low value-added low-tech, high-energy-consumption links, where countries engaged in can only obtain lower profits (Wang et al., 2017; Del et al., 2018; Mouanda, 2019; Wang J. C. et al., 2021).

The remarkable improvement of living standards has enhanced people's awareness of environmental protection and sustainable development. The concept of sustainable development has been widely accepted. Industrial upgradation and international production cooperation have an important impact on the global environment. The industrial structures of developing countries such as China and India face the dilemma of "low-end locking" when participating in the GVC, intensifying pressure on reducing carbon emissions domestically (Wang et al., 2022). Therefore, governments around the world have strengthened policies, which implicitly or explicitly increase the production cost, meeting the Millennium Development Goals (MDGs). The environment becomes an input factor of production and, hence, can change comparative advantages across countries (Hamamoto, 2006; Arouri et al., 2012; Albrizio et al., 2017).

The increasing international division of production and the stringent environmental policies coexist, which lets people focus more on the research on the relationship between environmental regulation and the GVC. Numerous studies have shown that environmental regulation policies have various impacts on enterprise innovation, productivity, upgrading of industrial structure, FDI, and so on, but few on the GVC. In addition, prior studies mainly focus the impact of environmental regulation on the manufacturing industry of a country or region. The expansion of the GVC in services has been stimulated recently by transnational corporations. Although the service sectors are "smoke-free" industries relative to the manufacturing sectors, the impact of environmental regulation on the GVC position in service sectors need to be further tested and analyzed.

Based on the aforementioned theoretical and practical background, this study attempts to answer the following questions: 1) what is the impact of environmental regulation on GVC position in service sectors and what is the theoretical mechanism of the impact? 2) What is the heterogeneity of this impact across countries with different economic development level?

The major contributions of this study lie in the following three aspects: first, we theoretically analyze the mechanism on how the environmental regulation affects the GVC position in service sectors, which is a new research perspective on GVC. Second, we use the latest value-added decomposition method to measure the GVC position in service sectors and get the GVC position index in service sectors from selected 41 major economies, which add the data of the service industry's value chain position for GVC research. Third, we find that environmental regulation has significantly promoted the increase of GVC position in service sectors, which obviously can verify the validity of the Porter hypothesis.

The article is organized as follows. Section 2 puts forward the research hypothesis after reviewing the literature. Section 3 measures the indicator used in the empirical analysis. Section 4 describes the construction of an econometric model and describes the variables and data source. Section 5 presents estimation results with corresponding interpretation, and numerous robustness tests are applied. Section 6 concludes and discusses policy implications. Some detailed summary of descriptions and results are provided in appendices.

# 2 Literature review and hypothesis

## 2.1 Literature review

The literatures focus on the impact of environmental regulation in a country or region, mainly on the macro factors such as total factor productivity, industry development, trade flow, international competitiveness, and so on. The mechanisms mainly revolve around the Porter hypothesis and the pollution haven hypothesis (PHH).

### 2.1.1 Porter hypothesis and related studies

According to neoclassical economics, environmental regulation will increase private production costs and reduce the competitiveness of enterprises, thus offsetting the positive effects of environmental regulation on society and producing negative effects on economic growth. Jaffe et al. (1995) pointed out that the reason why the U.S. economy has experienced a trade deficit for more than a decade is the environmental regulation policy implemented by the U.S. government in recent years. Environmental protection leads to high economic costs, which seriously hinders the productivity growth of manufacturers and their competitiveness in the international market. However, Porter, Linde, and other scholars believed that the relationship between environmental regulation and economic development cannot be simply divided into two opposites. They believe that appropriate environmental regulation can promote enterprises to carry out more innovation activities, which will improve the productivity of enterprises, offset the costs brought by environmental protection, and enhance the profitability of enterprises in the market. This is Porter's hypothesis (Michael, 1991; Michael and Claas, 1995). The Porter hypothesis holds that the main way for environmental protection policies to have an impact on the economy is to promote enterprises to carry out technological innovation or adopt innovative technologies. Although it may increase costs in the short term, it can improve enterprise production efficiency, increase enterprise competitiveness, and promote economic growth in the long

term, which we call "innovation offsets". The Porter hypothesis also affirms the role of the government in coordinating the relationship between economic growth and environmental protection policies. First, it is difficult for enterprises to have sufficient information on innovation technology related with environmental regulation, whereas the government has a natural advantage in obtaining relevant information. Second, the government should design appropriate mechanisms and make use of market forces to guide enterprises to implement environmental regulation.

Since the Porter hypothesis was put forward in 1991, whether environmental regulation can improve the competitiveness of enterprises has become an academic debate. On one hand, the view that environmental regulation will enhance competitiveness is highly supported (Michael and Claas, 1995; Murty and Kumar, 2003; Hamamoto, 2006; Bohringer et al., 2012). For example, Wang S. et al. (2021) found that there exists a positive effect of environmental regulation on China's industrial sector position in the GVC, which means that environmental regulation has significantly upgraded the GVC position. Chen et al. (2022) found that environmental regulation have significantly increased the markups of export products, which indicated that environmental regulation improved the firms' export competitiveness. On the other hand, some previous studies do not support the Porter hypothesis. For example, Van and Cees, 1997 analyzed the relevant data of OECD countries using the gravity model and concluded that the stringent the environmental regulation will lead, the higher the environmental cost, thus reducing export competitiveness. Wang and Zhang (2022) found that some Chinese firms had to cut production and went bankrupt finally because of the increasing production cost caused by environmental regulation. Hancevic (2016) found that environmental regulations had a negative effect on the productivity of electricity generation in the American power industry, whereas Stoever and Weche (2018) drew a conclusion that water taxes had reduced the overall competitiveness of firms in Germany. Domazlicky and Weber (2004) did not find that environmental regulation would inevitably reduce the production efficiency in the empirical analysis of the American chemical industry.

### 2.1.2 Pollution haven hypothesis and related studies

The standard trade theory holds that trade liberalization will make the polluting industries of developed countries with strict environmental regulation migrate to developing countries with loose environmental standards, which make the developing countries become "pollution havens" for specialized production of polluting products. The process of offshoring production to developing countries caused by environmental regulation is known as PHH. The hypothesis holds that under other conditions unchanged, industries with high energy consumption and high pollution will flow from countries with strict environmental protection policies to countries with relatively loose policies (Copeland and Taylor, 1994; Batabyal, 1998). Since the 1960s and 1970s, the global industrial structure began to shift. First, labor-intensive industries flowed from Europe and the United States to Japan and then to South Korea, Singapore, Taiwan, China, and Hong Kong. In the 1980s, with the implementation of opening-up policies in some countries in Asia and Latin America, industrialization extended to these regions. Although the transfer of global industrial structure is the result of multiple factors, it is not unrelated to the environmental policy. PHH has been extensively discussed for more than 30 years. The outward transfer of carbon-intensive industrial activities is undoubtedly a beggar-my-neighbor policy (Brunnermeier et al., 2004; Raspiller and Riedinge, 2005; Levinson and Taylo, 2008; Kalamova and Johnstone, 2012; Kahouli et al., 2014; Zhong et al., 2021; Qi et al., 2022; Wang and Zhang, 2022).

The validity of the PHH has also been mixed. In recent years, economists from Norway, Germany, and the United States have analyzed the carbon emissions from economic sectors and confirmed the existence of a "pollution paradise". For example, Tomasz and Christina (2016) found that developed countries use international trade to transfer the pressure of emissions to the outside while stabilizing or reducing their carbon emissions. Duan et al. (2021) used the multi-country input–output model to test the PHH in the context of the GVC and found that PHH was also valid in value-added trade. Zhao et al. (2013) empirically tested the PHH in combination with China's trade model, and the empirical result supported this hypothesis. However, Nathaniel et al. (2020) studied the impact of FDI on the ecological environment of countries along the Mediterranean coast and found that the PHH is not tenable in this region. Hu et al. (2021) found that the rise of the GVC position significantly promotes the green technology innovation efficiency. Wang S. et al. (2021) studied the relationships among the degree of participation in the GVC, technological progress, and environmental pollution from the perspective of industries in developing countries and found that the GVC reaches a certain level, and technology can reduce pollution.

## 2.2 Research hypothesis

Although the GVC approach is originally developed for goods production, the ever-changing communication and information technology makes it possible for many services that could not be provided across borders. Transnational companies take advantage of the low-cost and skilled labor force in developing countries to integrate the middle- and low-end activities of some service sectors, such as customer service center, business process, and non-core parts of accounting services, to further reduce their operating costs

and expand profit margins. A major part of the growth in world trade in services is explained by the development of the GVC in service sectors. Some developing countries with the earliest export outsourcing services, such as India and the Philippines, have begun to turn to outsourcing services with higher added value, such as R&D, financial analysis, and legal analysis (Apte and Richard, 1995; Gereffi and Fernandez, 2011). For the developing countries, the opportunities for exporting services are, therefore, largely tied to the insertion they can achieve within the GVC, either in specifically service chains (e.g., banking services, audiovisual materials, advertising, health services, etc.) or in service linkages in manufacturing chains (e.g., logistic services, R&D, business, etc.) (Lopez et al., 2011).

The characteristics of the GVC in service sectors determine that the effect of environmental regulation on it is different from that on the manufacturing industry. First, the implementation of strict environmental regulation will increase the service cost and decrease the service supply of pollution-intensive service sectors. In order to avoid losses, some service supplies will spontaneously be transferred to countries with loose environmental regulation. The clean intensive service sectors will increase their share and realize the adjustment of industrial structure. Second, the service industry itself is a clean industry, and its cost is not easily affected by environmental policies. Thus, the implementation of environmental regulation will lead to increase in the relative cost of manufacturing sectors to the service industry. Based on the rational decision-making of consumers, services will replace commodities to realize the optimization and upgradation of the service sectors. Third, the implementation of strict environmental regulations can improve the ecological environment and produce positive external benefits, which will make the service sectors more profitable and further promote the development of local transportation, accommodation, catering sectors, and so on.

Based on the characteristics of the GVC in service sectors and aforementioned analysis, this study proposes the following hypotheses:

**Hypothesis 1.** The implementation of environmental regulation can promote the GVC position in service sectors.

When a country implements strict environmental regulation policies, service sectors have to pay extra environmental costs; thus, the service costs get higher. Based on the assumption of economic rationality, enterprises will carry out innovation and R&D activities to reduce costs. Environmental regulation forces enterprises to make technological progress and enhance their international competitiveness and then improve the GVC position.

**Hypothesis 2.** The influence of environmental regulation on GVC position in service sectors is heterogeneous.

On one hand, there are differences in the intensity of environmental regulation across countries. Generally speaking, countries with high per capita income are more inclined to formulate and implement stringent environmental regulation than countries with low per capita income. The higher the intensity of environmental regulation, the more effective it will be in promoting the GVC position. On the other hand, countries with different levels of development have different effects of environmental regulation on GVC position in service sectors.

# 3 Calculation of the indicator

## 3.1 Calculation of environmental regulation

Referring to the method proposed by Lu (2009) and Chakraborty and Mukherjee (2013), this study uses the environmental performance index (EPI) as an indicator for environmental regulations. The EPI provides a powerful policy tool to reflect the government's implementation of environmental goals, which can help countries identify problems and formulate better environmental policies to support the efforts to achieve the United Nations sustainable development goals and promote society toward a sustainable future.

### 3.1.1 Construction of the environmental performance index index

EPI scores and ranks countries or regions according to 32 performance indicators into 11 issue categories, including environmental health and ecosystem vitality. Table 1 shows the composition and weight decomposition of the EPI (Yale Center for Environmental Law and Policy, 2022).

### 3.1.2 Results of the environmental performance index index

In order to get in line with the GVC position index, this study analyzes the EPI of the selected 41 sample countries during the even years of 2006–2014, including 33 high-income countries (Australia, Austria, Belgium, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States) and eight middle-income countries (Brazil, Bulgaria, China, India, Mexico, Romania, Russia, and Turkey). The division of high-income countries and middle-income countries is based on the identification of the national income level in the Asian Bank Database (ABD).

Figure 1shows the trend of the EPI in high-income countries. Overall, the countries with high scorers formulate and implement the long-term environmental protective policies and plans to

TABLE 1 Composition and weight decomposition of the EPI.

| Objective | Weight (%) | Issue category | Weight (%) | Indicator | Weight (%) |
|---|---|---|---|---|---|
| Environmental health | 40.0 | Heavy metals | 2.0 | Lead | 2.0 |
| | | Waste management | 2.0 | Solid waste | 2.0 |
| | | Air quality | 20.0 | PM 2.5 exposure | 11.0 |
| | | | | Household solid fuels | 8.0 |
| | | | | Ozone exposure | 1.0 |
| | | Sanitation and drinking water | 16.0 | Drinking water | 9.6 |
| | | | | Sanitation | 6.4 |
| Ecosystem vitality | 60.0 | Water resources | 3.0 | Wastewater | 3.0 |
| | | Agriculture | 3.0 | SNMI | 3.0 |
| | | Pollution emissions | 3.0 | $NO_X$ | 1.5 |
| | | | | $SO_2$ | 1.5 |
| | | Ecosystem services | 6.0 | Wetlands | 0.3 |
| | | | | Grasslands | 0.3 |
| | | | | Tree cover | 5.4 |
| | | Fisheries | 6.0 | Stock status | 2.1 |
| | | | | MTI | 2.1 |
| | | | | Trawling | 1.8 |
| | | Biodiversity and habitat | 15.0 | BHI | 1.5 |
| | | | | SHI | 1.5 |
| | | | | PARI | 1.5 |
| | | | | SPI | 1.5 |
| | | | | Biome protect (global) | 3.0 |
| | | | | Marine protection | 3.0 |
| | | | | Biome protect (national) | 3.0 |
| | | Climate change | 24.0 | Black C | 1.2 |
| | | | | $CH_4$ | 3.6 |
| | | | | $NO_2$ | 1.2 |
| | | | | GHG pop | 0.6 |
| | | | | GHG Int. | 1.2 |
| | | | | F-Gas | 2.4 |
| | | | | $CO_2$ | 13.2 |
| | | | | Land cover | 0.6 |

defend public health, preserve natural resources, and decrease greenhouse gas emissions. With its outstanding performance in climate change, agriculture, fisheries, forests, water sources, air pollution and environmental burden, Switzerland once again ranked first in 2014. While high-income countries are commendable in many aspects, such as expanding the coverage of safe drinking water and sanitation facilities and reducing child mortality, trends in other areas are worrying, such as fishing, wastewater treatment, and air quality. Sweden and Norway follow closely, and Luxembourg, the United Kingdom, and Finland also have high levels of environmental regulation. Malta's EPI has the largest fluctuation range, increasing from 47 to 67. The United States, the largest economy in the world, is at a low level among high-income countries in terms of the EPI.

Compared with the group of high-income countries, the EPI of middle-income countries is generally lower. Figure 2 shows the trend of EPI in middle-income countries. Among the eight middle-income countries, India's EPI is often at the lowest level compared with other countries in the same period, with the lowest value of 31 and the highest value of 52. From 2006 to 2014, Brazil's EPI decreased from 61 to 53, indicating that Brazil is gradually deregulating. The EPIs of Mexico and Russia have roughly the same trend. The EPI of China ranges from 40 to 45, which is only higher than that of India in some years. Surprisingly, China's performance in carbon reduction is very eye-catching. In the past 10 years, China is the only developing country that has achieved the same rate of carbon reduction and greenhouse gas increase. On the whole, some middle-income countries are gradually attaching importance to environmental

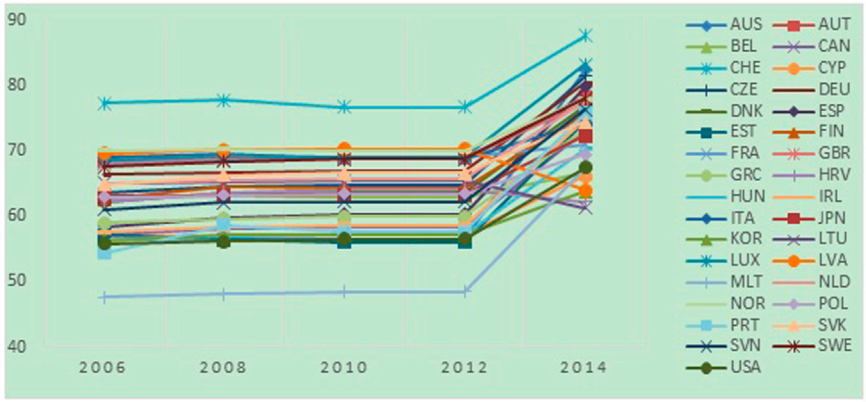


FIGURE 1
Trend of the EPI in high-income countries.

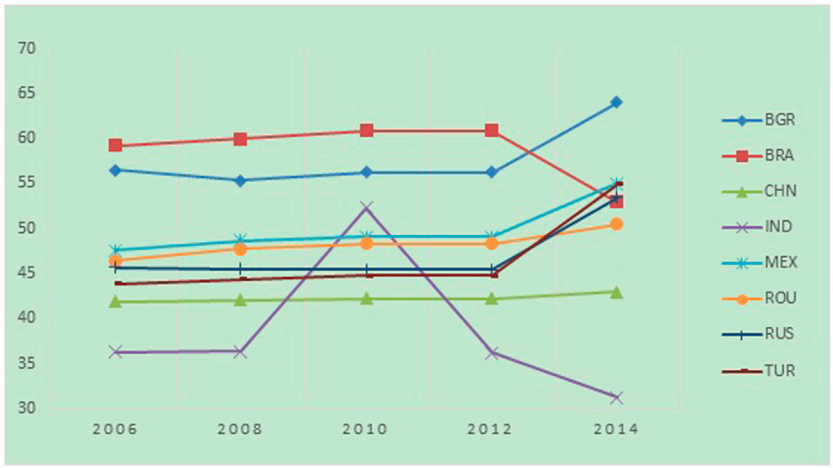


FIGURE 2
Trend of the EPI in middle-income countries.

problems and trying to solve the increasingly serious environmental problems, causing the EPI to increase.

In addition, if we compare the EPI between the group of high-income countries and the group of middle-income countries, we can find that the standard deviation of the EPI in middle-income countries is larger (see Supplementary Appendix Table SA1), indicating that the EPI fluctuates more violently. There is still an obvious gap in the EPI between high-income countries and middle-income countries, which provide convenience that countries with high per capita income are more inclined to formulate and implement stringent environmental regulation than countries with low per capita income.

## 3.2 Measuring the global value chain position in service sectors

### 3.2.1 Construction of the index of global value chain position in service sectors

Since 2001, scholars have carried out significant research on the GVC. In view of the heterogeneity of industrial attributes, the systematicness of data sources, the differences in the scope of application of indicators, and the measurement results of various industries embedded in the GVC are different. How to quantify the specific embedded position of a country or industry in the GVC has not yet formed a unified measurement standard. The

representative methods to measure the status of the GVC in the existing research mainly include the vertical specialization index, export product price index, export technology complexity index, GVC status index, and upstream index (Michaely, 1984; Hummels et al., 2001; Schott, 2004; Koopman et al., 2010).

Koopman et al. (2010) first proposed the GVC status index to measure a country's GVC position in a specific sector. They believed that even if the two countries participate in the international division of labor to the same extent, the division of labor status reflected in the value chain would be different. Therefore, based on the input–output method, they proposed a macro measurement method to reflect the status of a country in the GVC. Specifically, the GVC status index reflects the difference between the logarithm of intermediate goods exported by an industry of a country to other countries and the logarithm of imported intermediate goods included in the exports of that industry. This study uses Koopman's method to measure the GVC position index in service sectors. The specific formula is as follows.

$$GVC\_Position_{ir} = Ln\left(1 + \frac{IV_{ir}}{E_{ir}}\right) - Ln\left(1 + \frac{FV_{ir}}{E_{ir}}\right). \quad (1)$$

In Eq. 1, the subscripts i and r denote the service sector and country, respectively. $GVC\_Position_{ir}$ is the index of the GVC position in service sector i of country r. $IV_{ir}$, $FV_{ir}$, and $E_{ir}$ represent the indirect added-value export, the added value of intermediate exports of exporting countries, the total export value, respectively. $IV_{ir}/E_{ir}$ is GVC's forward participation index in service sector i of country r, which indicates the extent to which intermediate products exported by service sector i of country r are used by the importing country to produce final products and exported to a third country. The higher the value of $IV_{ir}/E_{ir}$, the more the service sector i of country r is in the upstream of the GVC. Then $FV_{ir}/E_{ir}$ is GVC's backward participation index of in service sector i of country r, which is the rate of foreign added value in exports. The higher the value of $FV_{ir}/E_{ir}$, the more the service sector i of country r is in the downstream of the GVC. The measurement of the GVC position index in service sectors is that the logarithm of the GVC's forward participation index minus the logarithm of the GVC's backward participation index.

When participating in the division of labor in the GVC, a country plays two roles: the supplier of intermediate inputs (measured by the value added of exports) and the demander (measured by indirect value-added exports). If it plays a more supplier role, it means that the country is in the upstream of the GVC. The greater the GVC status index, the closer it is to the upstream of the GVC, and the higher the international division of labor. In contrast, the smaller the GVC status index, the closer it is to the downstream of the GVC, and the lower the division of labor status (Qu et al., 2020). Regarding the classification standard of the service industry, this study selects 32 service sectors (see Supplementary Appendix Table SA2) based on the classification standard of the World Input–Output Database (WIOD).

### 3.2.2 Results of the global value chain position index in service sectors

Using the world input–output table provided by WIOD (Timmer et al., 2015), this study calculates the *GVC_Position* in the same sample countries and the same period in line with the EPI (see Supplementary Appendix Table SA3). The top ten countries of *GVC_Position* in service sectors are Russia, Brazil, the United States, Australia, the United Kingdom, Italy, Portugal, China, Turkey, and India. These countries include both high-income and middle-income countries. The *GVC_Position* in service sectors of Russia is always higher than that of other countries, indicating that Russia's service sectors are in the upstream position of the GVC. The *GVC_Position* in service sectors of Belgium, the United Kingdom, and Ireland show a downward trend, while the *GVC_Position* in service sectors of middle-income countries shows a downward trend since they actively imitate and innovate and continuously improve the export level of the service sectors.

## 4 Econometric model, variables, and data

### 4.1 The model construction

On the basis of the previous theoretical analysis and hypothesis, this study explores the effect of environmental regulation on the GVC position in the service sectors and constructs a fixed-effect panel data econometric model, as shown in Eq. 2:

$$GVC\_Position_{ir} = \alpha + \alpha_1 LnEPI_{it} + \alpha_2 Ln\,CS_{it} + \alpha_3 LnR\&D_{it} + \alpha_4 LnFDI_{it} + \varepsilon_{it}. \quad (2)$$

In Eq. 2, the subscripts i and t denote the service sector and year, respectively.*GVC_Position*, *EPI*, *CS*, *R&D*, and *FDI* represent the GVC position in service sectors, intensity of environmental regulation, capital stock, intensity of R&D, and foreign direct investment level, respectively. $\alpha$ and $\varepsilon$ denote the constant term and the error term, respectively. Since the measurement of *GVC_Position* is the logarithmical form, all variables on the right of Eq. 2 are logarithmically treated in order to avoid the influence of heteroscedasticity and time trend on the regression results. Then, the estimation coefficient can be interpreted as the elasticity of independent variables with respect to the dependent variable (*GVC_Position*).

TABLE 2 Descriptive statistics of variables.

| Variable | Symbol | Definition | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|---|
| Dependent variable | *GVC_Position* | GVC position index in service sectors | 205 | 0.2985 | 0.1463 | −0.2967 | 0.5881 |
| Independent variable | *EPI* | EPI index | 205 | 4.1132 | 0.1717 | 3.4413 | 4.4742 |
| | *EPI*1 | Environmental health index | 205 | 4.4467 | 0.2461 | 3.2067 | 4.6057 |
| | *EPI*2 | Ecosystem vitality index | 205 | 3.8980 | 0.2018 | 3.3715 | 4.4391 |
| Control variables | *CS* | Ratio of total capital formation to GDP | 205 | 3.1713 | 0.2309 | 2.4762 | 3.8411 |
| | *R&D* | Ratio of R&D expenditure to GDP | 205 | 0.2873 | 0.6222 | 0.9968 | 1.4067 |
| | *FDI* | Ratio of net inflow of FDI to GDP | 205 | 1.2301 | 1.5228 | −6.3949 | 5.9120 |

## 4.2 Variable selection

In this study, *GVC_Position* and *EPI*, as introduced previously, are selected as the dependent variable and the core independent variable, respectively. In order to further explore how environmental regulation affects the GVC position in service sectors, we decompose the core independent variable into two indicators, namely, *EPI*1 and *EPI*2, which represents environmental health and ecosystem vitality, respectively. The division is based on the overall goal of the EPI: maintaining environmental health and improving ecosystem vitality. In addition, the following variables are selected as control variables in the light of the robustness of the estimation results and the explanatory power. The definitions and descriptive statistics of the main variables are shown in Table 2.

(1) Capital stock (*LnCS*): The difference of factor endowments can better-explain the causes of international trade and can best-reflect the heterogeneity between countries. Referring to the method of Xie et al. (2018), this study takes the ratio of a country's total capital formation to its GDP as a capital stock.
(2) Intensity of R&D (LnR&*D*): R&D investment is the most important source of productivity growth. Countries with stronger R&D and innovation capabilities have stronger social productivity, and their enterprises have more competitive advantages. Under strict environment regulation, the enterprises need to carry out independent innovation, improve green productivity, and achieve the rise of GVC position. This study uses the ratio of R&D expenditure to GDP to represent R&D intensity.
(3) Intensity of utilization of foreign capital (*Ln* FDI): The FDI is an important factor affecting the added value of the export trade. Generally speaking, the FDI exerts an effect on the domestic added value of enterprises' export through two paths: direct impact and indirect impact. The direct impact is through the input of imported intermediate goods, and the indirect impact is through the technology spillover effect of FDI, including demonstration and imitation, human capital flow, export, competition, and correlation effects. This study uses the ratio of net inflow of the FDI to GDP to represent utilization of foreign capital intensity.

## 4.3 Data source

The data required to calculate the *GVC_Position* come from the World Input–Output Database (https://www.rug.nl/ggdc/valuechain/wiod). It consists of a series of databases and covers 28 EU countries and 15 other major countries in the world for the period from 2000 to 2014, which mainly displays the input–output matrix of each industry, and we can use Eq. 1 to calculate the trade added value. We use the *EPI* to measure the intensity of environmental regulation in different countries, and the data are obtained from the Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network Earth Institute, Columbia University (https://epi.yale.edu). Data on capital stock, intensity of utilization of foreign capital, and intensity of R&D are all obtained from the World Bank (https://data.worldbank.org). The sample countries are 41 countries jointly matched by WIOD and World Bank's database. Since the *EPI* has been released every even year since 2006 and the newest WIOD is released in 2016, we select the relevant data of 41 countries in 2006, 2008, 2010, 2012, and 2014.

# 5 Empirical results

## 5.1 Unit root test and cointegration test

The sample data need to be tested for stationarity before panel data regression in order to ensure the reliability and the accuracy. In this study, LLC, IPS, HT, ADF-Fisher, and Hardy LM test methods are selected to carry out the unit root test. Table 3 shows that all the tests reject the original hypothesis at the level of the 1% unit root test, that is, no unit root is found in the

TABLE 3 Results of unit root test for primary variables.

| Method | *GVC_Position* | *EPI* | *CS* | *R&D* | *FDI* |
|---|---|---|---|---|---|
| LLC | −16.6356 | −9.0811 | −7.0203 | −11.3568 | −12.0426 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| IPS | −10.3215 | −12.2573 | −8.17651 | −10.1775 | −10.4374 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| HT | 0.1432 | −0.0658 | 0.1659 | 0.3697 | 0.1128 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| ADF-Fisher | 150.8765 | 143.6589 | 84.9848 | 156.8365 | 128.3341 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Hadri LM | 5.0061 | 2.8111 | 6.7876 | 9.5648 | 21.7891 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |

Note: The numbers in parentheses are *p*-value.

TABLE 4 Cointegration test results.

| Test | Name | Statistic | *p*-value |
|---|---|---|---|
| KAO | Modified Dickey–Fuller test | −4.9675*** | 0.0000 |
| | Unadjusted modified Dickey–Fuller test | −35.0769*** | 0.0000 |
| | Unadjusted Dickey–Fuller test | −20.5550*** | 0.0000 |
| Pedroni | Modified Phillips–Perron statistic | −3.6054*** | 0.0002 |
| | Phillips–Perron statistic | −16.1858*** | 0.0000 |
| | ADF statistic | −12.5369*** | 0.0000 |

Note: ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively.

model. Therefore, we can assume that the variables in the model are one-order, single-integral stable variables.

In order to further test whether there is a long-term stable equilibrium relationship between variables, the Pedroni and Kao cointegration test is used in this study to avoid false regression, and the results are shown in Table 4. Pedroni and Kao tests reject the original hypothesis at the level of the 1% cointegration relationship, which means there is a long-term stable equilibrium relationship between variables in the model, and the regression residuals of the model are stationary.

TABLE 5 Effects of EPI on the GVC position in service sectors for 41 major economies.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *Ln* EPI | 0.136*** | 0.116** | 0.118** | 0.132*** | | | | |
| | (3.3578) | (2.5003) | (2.4787) | (2.6941) | | | | |
| *Ln* EPI1 | | | | | 0.133*** | | 0.149*** | |
| | | | | | (3.3397) | | (2.4345) | |
| *Ln* EPI2 | | | | | | 0.069 | | 0.036 |
| | | | | | | (1.258 2) | | (0.6817) |
| *Ln* CS | | 0.043 | 0.030 | 0.004 | | | 0.024 | 0.087* |
| | | (0.8607) | (0.6484) | (0.0787) | | | (0.4267) | (1.9406) |
| *Ln* R&*D* | | | 0.015 | 0.018* | | | 0.027* | −0.005 |
| | | | (0.8852) | (1.0430) | | | (1.9630) | (−0.3007) |
| *Ln* FDI | | | | 0.038*** | | | 0.032*** | 0.040*** |
| | | | | (5.5957) | | | (5.3791) | (5.8725) |
| C | 0.903*** | 0.680** | 0.767** | 0.916*** | 0.906*** | 0.030 | 0.823*** | −0.068 |
| | (5.0087) | (2.1503) | (2.4585) | (2.7244) | (4.9736) | (0.1387) | (2.1072) | (−0.2477) |
| N | 205 | 205 | 205 | 205 | 205 | 205 | 205 | 205 |
| $R^2$ | 0.753 | 0.806 | 0.815 | 0.823 | 0.874 | 0.892 | 0.749 | 0.895 |

Note: ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively. The numbers in parentheses are the standard deviations of the regression coefficients.

## 5.2 Baseline results

According to Eq. 2, we empirically analyze the effect of environmental regulation on the GVC position in service sectors and perform panel regression on the sample variables. The model regression is carried out with STATA16.0 software. The regression results are shown in Table 5.

Columns (1)–(4) in Table 5 are the regression results by adding control variables one by one. As Table 5 shows, the regression coefficient of *Ln* EPI in the columns (1)–(4) is all significant at the 5% level, and the regression coefficient is 0.136, 0.116, 0.118, and 0.132, respectively. The results verify that environmental regulation does have a positive impact on the GVC position in service sectors, which verify the validity of Hypothesis 1 mentioned in Section 2. For the control variables, the regression coefficient of *Ln* R&*D* is 0.018 in columns (4), which confirms the "innovation offset" effect. When enterprises are subject to strict environmental regulation from outside, the cost will increase. Enterprises will strengthen independent R&D and improve green productivity to reduce the negative impact of environmental regulation. The regression coefficient of *Ln* FDI is 0.038 and significant at the level of 1%, which shows that the higher the ratio of net inflow of FDI to GDP, the more it can promote the GVC position in service sectors. In addition, the regression coefficient of *Ln* CS is not significant, indicating there is a weak relationship between the GVC position in service sectors and capital stock. Blindly increasing physical capital will not have a significant impact on the promotion the GVC position in service sectors.

Columns (5)–(8) in Table 5 are the regression results of EPI decomposition. The regression coefficient of LnEPI1 is significant at the 1% level, whereas the regression coefficient of LnEPI2is not significant, which indicates that environmental health has a more prominent positive impact on the GVC position in service sectors than ecosystem vitality. This point can be explained as follows: the objective of EPI1 is environmental health, and its subordinate indicators are mostly related to pollution links. The objective of EPI2 is ecosystem vitality, which mainly measures the development indicators in the ecosystem such as agriculture, forestry, fishery, etc. It is obvious that our environmental regulation is more inclined to the sectors that produce pollution, so EPI1 is more significant and can more effectively enhance the GVC position in the service sectors.

## 5.3 Quantile regression results

Generally speaking, the result of traditional regression analysis only shows an overall average effect of the explanatory variables. The different effects of the independent variables on the dependent variables under different quantiles have not been explained (Koenker, 2005; Yang and He, 2010). In order to accurately describe the overall effect of the conditional distribution of the EPI on the GVC position in service sectors, this study uses the conditional quantile regression.

Table 6 reports the results based on the quantile regression model. Columns (1) and (2) of Table 6 present the empirical results based on the median of *GVC_Position*. When *GVC_Position* is larger than the median of 0.325, the regression coefficient of *Ln* EPI is 0.12 and significant at the 5% level. While *GVC_Position* is smaller than the median of 0.325, the regression coefficient of *Ln* EPI is 0.054 and significant at the 10% level. This empirical result signifies that irrespective of the *GVC_Position* of the sample economies, the implementation of environmental regulation can have a positive impact on improving the GVC position in service sectors. Moreover, the effect is stronger in countries with a higher degree of development of service sectors. Therefore, this empirical result verifies the validity of Hypothesis 2 mentioned in Section 2.

From a worldwide perspective, countries with a high level of service industry development also have a strong comprehensive national strength and a first mover advantage in the process of industrial upgrading. They have transferred some high pollution and high energy consumption production departments to countries with a low level of development by looking for pollution shelters. This is consistent with the north–south trade model (Chichilnisky, 1994). Therefore, for countries with a high degree of development of the service industry, strict environmental regulation can significantly promote the GVC position in service sectors.

Columns (3) and (4) of Table 6 present the empirical results based on the median of the EPI. When *Ln* EPI is larger than the median of 4.54, the regression coefficient of *Ln* EPI is 0.17 and significant at the 5% level. While *Ln* EPI is smaller than the median of 4.54, the regression coefficient of *Ln* EPI is 0.123 and significant at the 10% level. This empirical result verifies the validity of Hypothesis 2 mentioned in Section 2 again. The greater the intensity of environmental regulation is, the more effect on the promotion of GVC position in the service sectors, that is, within a reasonable range, continuously improving the intensity of environmental regulation can improve the international competitiveness of the service industry so as to make the service industry ascend to the upstream position of the GVC.

## 5.4 Endogeneity test

Prior studies found that endogenous issues consist of reverse causality, omitted variable, and measuring error, which might be caused by the bias and inconsistency in the estimation results (Bound et al., 1995; Klette and Griliches, 1996). This study adopts 2SLS estimation to avoid the possible endogenous problems of our econometric models. Considering that the causal relationship between environmental regulation and GVC position in service

TABLE 6 Quantile regression results.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | **GVC > 0.325** | **GVC < 0.325** | ***Ln* EPI > 4.54** | ***Ln* EPI< 4.54** |
| *Ln* EPI | 0.120** | 0.054* | 0.170** | 0.123* |
| | (3.6504) | (0.6507) | (1.0213) | (2.2632) |
| *Ln* CS | −0.092*** | 0.272*** | 0.126 | −0.054 |
| | (−2.7218) | (3.1783) | (1.4733) | (−0.8629) |
| *Ln* R&*D* | 0.026** | −0.019 | 0.028 | 0.007 |
| | (2.0318) | (−0.7658) | (1.0041) | (0.2797) |
| *Ln* FDI | 0.006 | −0.042*** | −0.021** | −0.076*** |
| | (1.1572) | (−4.0448) | (−2.4688) | (−6.5382) |
| C | 1.185*** | −0.811 | 3.437 | 1.110*** |
| | (5.1892) | (−1.4670) | (0.9923) | (2.8878) |
| N | 108 | 97 | 107 | 98 |
| $R^2$ | 0.852 | 0.885 | 0.748 | 0.812 |

Note: ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively. The numbers in parentheses are the standard deviations of the regression coefficients.

TABLE 7 Results of the 2SLS estimations for 41 major economies.

| | (1) | (2) |
|---|---|---|
| *Ln* EPI | 0.134** | 0.143** |
| | (2.4145) | (2.4896) |
| *Ln* CS | 0.036 | 0.018 |
| | (0.6351) | (0.2904) |
| *Ln* R&*D* | 0.021 | 0.023 |
| | (1.0302) | (1.1187) |
| *Ln* FDI | | −0.034*** |
| | | (−4.6368) |
| C | 0.815** | 0.912** |
| | (2.1837) | (2.2703) |
| N | 164 | 123 |
| $R^2$ | 0.814 | 0.819 |
| Kleibergen–Paap rk LM statistics | 85.46 | 74.35 |
| | (0.0002) | (0.0001) |
| Kleibergen–Paap rk Wald F statistics | 735.01 | 415.86 |
| | (16.7578) | (11.4562) |
| First stage results | | |
| *LLn*EPI | 0.142*** | |
| | (0.0284) | |
| *L2 Ln* EPI | | 0.319*** |
| | | (0.0346) |
| F-statistics | 465.07 | 154.9 |

Note: ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively. The numbers in parentheses are the standard deviations of the regression coefficients.

sectors may be bidirectional (Zhao et al., 2018; Wang et al., 2020), we use the first-order and second-order lag of EPI as instrumental variables, which can effectively alleviate the reverse causality and simultaneous causality.

Columns (1) and (2) in Table 7 show the results of the 2SLS estimations.*LLn*EPI and *L2 Ln* EPI represent the first-order and second-order lag of EPI, respectively. The coefficients of *LLn*EPI and *L2 Ln* EPI are positive and both significant at the 1% level, indicating that the reliability of the estimation results of the core explanatory variable is verified. The Kleibergen–Paap rk LM statistics and the Kleibergen–Paap Wald rk F statistics are 74.35 and 415.86, respectively, in the result of second-stage regression. Therefore, the null hypothesis of instrument variables that are insufficiently identified is rejected. In a word, the results indicate that the selected instrumental variables in this study are reasonable, and we consider the estimation coefficient of the core independent variable is reliable.

Additionally, by comparison with the OLS regression results in Table 5, we find that the estimated coefficients of EPI become bigger after the introduction of instrumental variables, which indicates that the endogenous problem in OLS results underestimates the role of environmental regulation in promoting the GVC position in service sectors.

# 6 Conclusion and policy implications

## 6.1 Conclusion

In general, this study studies how the environmental regulation affects the GVC position in service sectors on the basis of theoretical derivation and empirical research in a comprehensive way. It will contribute to a better understanding of the relationship between environmental regulation and GVC. The key findings of this research are as follows: 1) from the sample as a whole, the EPI of 41 countries has

not changed much during 2006–2014. The EPI in middle-income countries is generally lower than that in high-income countries. The GVC position in service sectors is also relatively stable with a small fluctuation range. 2) Environmental regulation has a significant positive effect on the GVC position in service sectors, which verifies the validity of the Porter hypothesis. That is, the GVC position in service sectors can be promoted by the implementation of stringent environmental regulation. 3) The important impact channel which environmental regulation affects the GVC position in service sectors is the increasing environmental health, rather than ecosystem vitality. Environmental health can more effectively enhance the GVC position in the service sectors. 4) There is heterogeneity in the role of environmental regulation in promoting GVC position in service sectors. The higher the per capita income, the stringent their environmental regulation, and the stronger their impact on GVC position in service sectors are.

## 6.2 Policy implications

Based on aforementioned conclusions, the following policy recommendations on how the government handles with the relationship between environmental regulation and the GVC position in service sectors are proposed in the end of study.

First, the government should promote the unification of environmental regulation and GVC promotion objectives. Many national environmental regulations are formulated for a single goal, focusing on how to achieve environmental governance and environmental construction, and have not been considered as a whole with other policy goals. For example, some environmental regulations blindly emphasize the emission reduction and lack of coordination with development goals. Meanwhile, there is often a lack of overall design of environmental policies in the process of formulating the regional economic development strategy. Therefore, environmental regulation should be integrated into the national strategic planning.

Second, middle-income countries still need to adjust environmental regulation policies to narrow the gap with high-income countries and enhance the relative GVC position in the service sectors under the low-carbon economy. Meanwhile, the government should improve the service level of the manufacturing industry. In the process of upgrading the value chain, the manufacturing industry will have a great demand for productive services in R&D, design, marketing, management, and logistics.

Third, countries, especially developing countries, need to actively participate in the division of labor in the global value chain of the service industry, improve the level of technological development, and achieve green and sustainable development. The government needs to optimize the business environment and attract high-quality foreign investment. The governments should further open up the service market and encourage foreign enterprises to invest in service sectors and increase the proportion of foreign direct investment on green technological innovation.

The last enlightenment is that in order to realize the common development of environmental and economic development, the government should deepen communication and coordination with service enterprises, timely convey accurate trade policy information to the market, and encourage them to participate in the GVC and enhance their competitiveness. Meanwhile, environmental regulation policy can solve the problem of market failure, and the negative externalities related to environmental pollution can be restrained by adopting measures such as regulation and taxation.

# Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

# Author contributions

Supervision, formal analysis, and writing—review and editing: HL; methodology and writing—original draft preparation: LC; conceptualization: YS.

# Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

# Publisher's note



# Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.1051015/full#supplementary-material

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