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The Decomposition of Information and Communication Technology Products Trading: A Case Study of China

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Abstract: Technology is recognised as one of the most important factors in world economic development, particularly contributing to the trade growth of information and communications technology (ICT) products. The decomposition of export growth has been a popular way to analyse how trade has been influenced since 2000. However, there is little investigation regarding the structure of ICT product trading of China, which is the de facto largest trader of ICT goods export and import. This paper contributes to the existing methods with a non-parametric model. The coefficient estimates which functions of their factors represent a dynamic analysis of the factors' influence on decomposed trade growth. The empirical study shows that China's strategy tends to be conservative, as the growth of trade to developed countries mostly came from the volume increase of existing trade lines instead of the increase of trade varieties. Suggestions include that the trade growth could benefit from resource reallocation in ICT industries and the procedure simplification of exporting ICT products. This paper also provides empirical evidence that the Belt and Road Initiative (BRI) increased the trading volume and frequency by completing the transportation chain and decreasing the variable trade costs. Furthermore, suggestions are provided on improving the impact on the globalisation of ICT.

Keywords: ICT products; trade growth; the intensive and extensive margins; strategy; policy

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1. Introduction

Following the fourth industrial revolution, there is a worldwide growing realisation that technology drives the transformation and economic development of industries. In July 2020, the Industrial Internet Consortium (IIC) announced the publication of the Digital Transformation in Industry white paper, which covered a wide range of technologies that can enable digital transformation (Buchheit et al. 2020). In the context of Industry 4.0, the Ministry of Industry and Information Technology (MIIT) of China began to invest in authorities, including the Chinese Academy of Engineering (Rana and Sharma 2021).

This movement follows the Chinese national strategic plan to develop further the manufacturing sector of China, branded as "Made in China 2025" (MIC 2025) in May 2015. The plan includes the adoption of information technology and the connection of small- and medium-sized companies with global production networks (Institute for Security & Development Policy 2018). It indicates that the information and communications technology (ICT) industry is fundamental to developing the manufacturing sector in China and boosts ICT product export.

However, in the aftermath of the global financial crisis, the export growth rate was highly volatile during the transformation of China's "world factory" (Yang and He 2017). The advantage of domestic productivity showed a limited effect on export growth. It was even argued that there was no evidence showing that China's ICT industry is more sophisticated than one would expect from its level of development (Van Assche and Gangnes 2010). In this paper, we are interested in a variety of factors that have a large influence on the structure of ICT product export growth and any changes of trading strategy that can improve the development of economics.

An empirical analysis of the dual-margin model of trade growth is involved in the study. The aggregate trade growth can be decomposed into intensive and extensive margins (Felbermayr and Kohler 2006). The intensive margin refers to the trade volume change of the established bilateral trade relationships (Felbermayr and Kohler 2006). In contrast, the extensive margin is considered when new trade relationships are established or existing ones are abandoned (Felbermayr and Kohler 2006).

The decomposition of trade growth into the intensive and extensive margins has been a popular way to study how the trade growth is influenced. For example, scholars concluded that the intensive margin of cultural products has a positive effect in the short term, while the extensive margin has a more stable and continuous impact on the growth of the export added value (Zhang and Yang 2021). This was recognised as an effective model in trade studies based on the inspiration of Melitz (2003), which was the first to consider the heterogeneity across firms to analyse trade growth. There are two directions of the studies: the macroeconomic (country) level and the micro-economic (particularly firm or product) level (Bernard et al. 2006).

The choice of which way to decompose at which level depends on the research's aim and the data available (Felbermayr and Kohler 2006). At the firm level, the exposure to trade could reallocate the distribution of firms; however, the study only works with the heterogeneity of firms (Melitz 2003). Kancs (2007) simplified Melitz (2003)'s model by not considering the effect of the domestic but only the exporting productivity on firm-level exports and concluded that a Bilateral Free Trade Area (BFTA) would benefit from the increase of the extensive margin in Balkans. Based on the nature of the data available, our study adopted the theoretical framework of Kancs (2007) to decompose the aggregate electronics trade growth into intensive and extensive margins.

This paper contributes to two levels of trade studies. First, the fixed effect model, which is used to investigate the effects on dual margins is non-parametric, while existing methods use parametric models. This non-parametric model provides a more flexible estimating progress with functional coefficients so that the effects of the factors can be analysed dynamically. Second, for the first time to the best of our knowledge, our quantitative analysis decomposes Chinese ICT products' trade growth based on the dual-margin model using an unique data set from 2000 to 2018.

There were a variety of important strategies announced during this period, such as the "Silk Road Economic Belt" in September 2013 and the Belt and Road Initiative (BRI), which was incorporated into the Constitution of China in 2017. This paper provides empirical evidence of the effects on the trade growth in close discussions with those strategies. Moreover, the Harmonised System used in this paper is the latest version reviewed by the World Customs Organisation, which is "HS2017". This allows our results to be highly related to the current strategies in China.

The structure of this paper is as follows. Section 3 introduces the data source, and Section 4.1 conducts an exploratory analysis of dual margins of trade. Section 4.2 shows an empirical study of the decomposition of China's ICT product trading from 2000 to 2018, including a non-parametric model, which establishes the factors' impact on the dual margins. It is followed by Section 5 with a summary of suggestions on policy and strategy. Finally, Section 6 concludes the study.

2. Theoretical Framework

2.1. Historical Background of Dual Margins

The theory of international trade, or the effect of international trade on economic growth, has been investigated since 1776 (Sen 2010). Although only considering homogeneous input of labour hours, the Ricardian doctrine was regarded as the basic premises of a theory of free trade (Sen 2010). Another famous version of the traditional free-trade doctrine was the Heckscher–Ohlin based on the factor-endowment model, where more factors were considered, such as consumer demand (Sen 2010). The traditional theory only focused on the intensive margin of trade, as the heterogeneity in productivity of firms was not considered.

At the end of the 20th century, the new trade theory, including the intra-industry trade, was different from the old in the increasing returns of scale economies, imperfect markets and product differentiation (Sen 2010). The differential products "in the simultaneous import and export of commodities classified in the product group (Greenaway and Milner 1983)" indicated the consideration of an extensive margin of trade only.

At the beginning of the 21st century, the "new-new" trade theory (Berke 2021), a microeconomic firm-level model, was built by Melitz (2003) with the inclusion of firm heterogeneity and based on the monopolistic competition models. They provided the conclusion that only the most productive firms can deal with sunk costs and fierce competition in the export market (Singh 2010). In addition, with the reduction of trade costs, not only would the firms already in the export market increase the trading scale but also the firms only producing for domestic markets may have the opportunity to join the exporting group. Thus, the trade growth can be decomposed into the amount increase of existing trade lines (intensive margin) and the increase of new trade lines (extensive margin). The extensive margin of trade measures the variety of trade products, while the intensive margin measures the trade amount of the existing lines. Furthermore, the trade growth of the existing lines may come from two aspects: price and quantity.

The decomposition can analyse the trade growth at the microeconomic firm level. Countries with more firms with existing trade lines can be influenced more easily by the competition of foreign complementary products. Thus, the encouragement of developing new trade lines can be beneficial to survival in the export market (Qian and Xiong 2010).

In conclusion, international trade theory was developed from either margin to both simultaneously, providing strategies in consideration of consumer preference, supply, technology differentiation, etc. The decomposition of trade growth also presents a model that can analyse the economic development at a microeconomic level.

2.2. Definition of Dual Margins

The theory defining the dual margins of trade can be divided into three levels: the product level, firm level and country level. The definition of product level was discussed incorporating the market. The intensive margin was determined by the trade-volume (trade size) change of the existing export products in the old market (Chaney 2008). The extensive margin was defined by the change of categories of export products in the market (Chaney 2008), including existing export products entering into a new market, new products entering into a given market or developing new markets.

At the firm level, the intensive margin is defined by the average value of exports by firms and the extensive by the number of varieties that are exported by firms to each destination country (Berthou and Fontagne 2011). Firm-level focuses on firm behaviours, such as the expansion of the firm size and the increase of firm numbers in foreign markets (Chaney 2008). Definitions of dual margins on the country level use the same scenario with the firm level. The intensive margin depicts the trade volume change of an existing bilateral trading relationship between country pairs, and the extensive margin reflects the newly established trading bilateral relationship between countries that have not traded with each other (Felbermayr and Kohler 2006; Helpman et al. 2008; Hummels and Klenow 2005).

This paper uses data from both developing and developed countries, including China, Japan, Korea, the US and the EU. As it is difficult to obtain firms' data in all countries and the trade with other countries is not in the scale of this research, the discussion on the dual margins in this paper will be on the product level. The trade data are at the HS 6-digit level from 2000 to 2018, which are introduced with details in Section 3.

The measurements of the dual margins on the product level vary from the simple statistic of the price and categories to different indices of trade growth. For example, Feenstra (1994) incorporated new product varieties directly into the import price index by a constant-elasticity-of substitution (CES) aggregator function to calculate the extensive margin. In this paper, we measure the dual margins by adapting the methodology in Kancs (2007), which will be discussed in detail in Section 4.1.

2.3. Crucial Factors in Trade Growth

Inspired by Kancs (2007), we consider six factors in the following three perspectives.

Trade cost refers to the total cost, apart from the production cost, before the products reach the consumers, including the transportation (and time), the political barrier of trade (tariff and non-tariff), contract enforcement, currency fluctuation, legal supervision, local distribution, etc. (Anderson and van Wincoop 2004). The trade cost is normally discussed in two categories: the variable and fixed cost (Kancs 2007; Melitz 2003). Following the theory of Kancs (2007), we measure the variable trade cost by the geographic distance between the bilateral trade pair of countries. As long distance will increase the transport cost, the geographic distance has a naturally direct impact on the trade growth. In addition, technology innovation can be beneficial from experience sharing and communication.

As of the importance of technology in trading (Sohag et al. 2015; Zameer et al. 2020), the geographic distance has an indirect impact on trade growth by increasing the convenience of technological communication. The fixed cost, called the entry cost, is a crucial factor in trading. Melitz (2003) presents a well-known statement of firm heterogeneity that only the most productive and efficient firms can survive in the export market (Singh 2010). Fixed entry cost in an existing bilateral relationship and adequate profit that can cover the cost will allow the firm to contribute to the trade growth.

Trade barriers includes variable trade barriers in the form of tariffs or transport fees, policy trade barriers, geographic or cultural distance, information services delivered through devices, such as computers. (Hanson and Xiang 2011). It was considered to have a negative relationship with the trade growth between countries with homogeneous economic and technology development (Madsen 2001, 2009). Madsen (2001) concluded that the imposition of the discretionary trade barriers was a crucial factor in the contraction in world trade.

The trade barrier exists between any country pair, and bilateral trade is also affected by their interaction with other countries, which is the concept of multilateral trade resistance (Anderson and van Wincoop 2003 cited by Magerman et al. 2013). The results in Magerman et al. (2013) showed that this factor had a strong and significant impact on both the intensive and extensive margins of trade. In this paper, we followed the theoretical framework of Kancs (2007), who adapted the method in Head and Mayer (2004), to measure this factor. We take the ratio of the market sizes of the trading pair to obtain the multilateral resistance. The other trade-barrier factor considered in this paper is the technical barrier of trade. It is measured by the notification times that the export countries send to their trading partner, which reflects their restriction on the technical barrier of trade.

Other common factors, including the market size and labour productivity, will also be considered in the model of the dual margins, as introduced in Section 4.2.

3. Data

The worldwide flows of goods traded across countries are recorded by a standard 6-digit level classification system (Cebeci 2012). The Harmonised System (HS) was first introduced by the World Customs Organisation (WCO) in 1988. Each time the WCO reviewed the HS, there would be a new classification named by "HS" and followed by the year of the major revision (Cebeci 2012). Based on the system "HS2017", which the China Customs use, this paper classifies the ICT products into three categories and 93 types in total, as summarized in Table 1.

Table 1. The categories and the "HS2017" code of the ICT products.

Product Type	HS2017 Code
Information communications and computer integrated manufacturing technology	842489,842710,842890,844331,844332,844399,845620, 845710,845811,845891,845910,845921,845931,845940, 845951,845961,845970,846011,846021,846031,846040, 846090,846120,846130,846150,846190,846221,846231, 846241,846290,846410,846490,847010,847020,847050, 847110,847330,847350,847950,847970,847989,847990, 848610
Electrical and electronic products	850819,850860,850870,851430,850490,851712,851770, 852352,853410,853710,854079,854110,854150,854190, 854210,854310,854320,851712,851718,851761,851769, 851770,852110,852210,852329,852341,852349,852351, 852359,852380,852510,852580,852610,852841,852851, 852861,852869,852871,852872,852873,852910
Electronic technology	901890,901819,903090

Since 2000, in the aftermath of the global financial crisis, there have been market shifts from the Global North to Global South in the world economy, as summarised by Yang and He (2017) from Horner (2014) and Gereffi (2014). China was also encountering the transformation of the "world factory". Thus, our topic of interest in this paper is based on the data between 2000 and 2018, including the following statistics (last accessed date: 7 May 2022).

- *Index of Economic Freedom* from The Heritage Foundation. https://www.heritage.org/index/
- *Trade flow* of countries from UNComtrade database. https://comtrade.un.org/Data/
- *Gross domestic product (GDP)* of countries from the World bank database. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
- *Labor force* of countries from the World bank database. https://data.worldbank.org/indicator/SL.TLF.TOTL.IN

4. Methodology

The intensive and extensive margins of trade are first estimated by adapting the theoretical framework of Kancs (2007). The theory starts by calculating the total value of exports by the products of the average value of each shipment and the number of shipments. By considering various factors, including the total labour force, multilateral resistance, variable and fixed trade cost, the average value of each shipment and the number of shipments can be obtained based on their positive or negative relationships. The dual margins can be estimated by re-evaluating the formula of the total value of exports. The estimation is followed by a comprehensive discussion of the ICT product trade between China and five other representative developed and developing countries from 2000 to 2018.

In the empirical study, the estimated dual margins will be used as the outcome on which the following factors build a non-parametric model to investigate their influence: the market size, the variable trade cost, the multilateral resistance, the trade freedom and the technical barrier of trade. The advantage of this model is to provide a tendency of the margin's change against each factor by the functional estimated coefficients. The results are followed by a summary of the empirical evidence of the factors' impact on the dual margins and the total trade growth.

4.1. Estimating Dual Margins

The equation of the aggregate trade growth was derived by defining the consumer preferences and optimal firm strategies and building the trade model based on the global general equilibrium (Kancs 2007). Following the notation used by Kancs (2007), the total value of exports from the origin country o to the destination country d can be calculated as follows.

$$E_{od} = e_{od} \times N_{od} \tag{1}$$
$$= \alpha \frac{L_o L_d}{L} \left(\frac{\theta_d}{v_{od}} \right)^{\gamma} C^{1-\frac{\gamma}{\sigma-1}} \tag{2}$$

where e denotes the average value of each shipment and N denotes the number of shipments; L denotes the total labour force, and L_o and L_d denote the labour force of the exporting country and the importing country; θ_d denotes the multilateral resistance of the destination country, v denotes the variable cost, and C denotes the fixed trade cost; the parameters α, γ and σ are all constants.

The potential endogeneity was considered by Kancs (2007) through a reverse causality where the trade growth can be a promotion of the labour demand; confounding factors can be influenced by the same event. Thus, the equation of the relative export growth $\Delta E = \frac{E_{od}}{E_{do}}$ was derived as follows.

$$\Delta E_{od} = (\Delta C_{od})^{1-\frac{\gamma}{\sigma-1}} (\Delta\theta_{do})^{\gamma} \tag{3}$$

where $\Delta C = \frac{C_{od}}{C_{do}}$ denotes the ratio of export entry costs and $\Delta\theta_{do} = \frac{\theta_d}{\theta_o}$ denotes the ratio of the multilateral resistance.

Kancs (2007) summarised from previous trade studies that the aggregated trade growth composes two elements: the amount change of existing product lines and the trade growth of new trade lines. We divide the relative trade growth into the intensive margin Δe_{od} and the extensive margin ΔN_{od} as follows.

$$\Delta e_{od} = \Delta C_{od}^{\frac{\gamma}{\sigma-1}} \tag{4}$$
$$\Delta N_{od} = \Delta\theta_{do}{}^{\gamma} \Delta C_{od} \tag{5}$$

The dual margins can be calculated by estimating the parameters γ and σ. With the time reference added into subscripts (Kancs 2007), the parameters can be estimated by the following gravity equation of trade flows from the exporting country o to the destination country d (the logarithm of Equation (3)).

$$\log \Delta E_{odt} = \beta_1 + \beta_2 \log \Delta C_{odt-1} + \beta_3 \log \Delta\theta_{dot-1} + v_{od} + \epsilon_{odt} \tag{6}$$
$$\beta_2 = 1 - \frac{\gamma}{\sigma - 1}, \quad \beta_3 = \gamma \tag{7}$$

where β_1 is the intercept, v_{od} represents the time-invariant fixed effect of the country-pairs, and ϵ is the random error. Due to the potential endogeneity of explanatory variables, two approaches are used to move around: involving the relative export flows instead of gross trade and lagging the explanatory variables by 1 (Kancs 2007). The logarithm of the fixed cost ratio can be calculated as follows (Qian and Xiong 2010).

$$\log \Delta C_{odt} = \log\left(1 + \frac{\phi_{ct}}{\phi_{dt}}\right) \tag{8}$$

where ϕ_{ct} and ϕ_{dt} are the index of economic freedom of China and the destination country. Similarly, the logarithm of the resistance ratio can be calculated as follows.

$$\log \Delta\theta_{dot} = \log\left(1 + \frac{L_d}{L}\psi_{odt}\right) \tag{9}$$

where L_d and L are the labour force of the destination country and the total labour force of the world; as introduced by Kancs (2007), ψ denotes the index of trade freedom, which is defined as follows.

$$\psi_{od} = \sqrt{\frac{E_{od}E_{do}}{E_{oo}E_{dd}}} \tag{10}$$

where E_{od} and E_{do} are the trade flows between the pair of countries; E_{oo} and E_{dd} are the country's GDP minus its trade flows.

An exploratory analysis of China's export to India, Japan, South Korea, the US and the EU from 2000 to 2018, based on the obtained dual margins is as follows. The intensive and extensive margins of the trade growth from China are shown in Figure 1 and Figure 2, respectively. By looking at each curve along the horizontal time scale, the longitudinal study from 2000 to 2018 shows a relatively different trend of dual margins of China's export to different countries. Although fluctuating, the intensive margins (Figure 1) of China to Japan, South Korea, the US and the EU have an increasing trend in general, indicating the advantage of China's existing electronic product export and an increase of the unit benefit of the products.

The reason can be found by an increasing global demand for electronic products, which has largely encouraged manufacturing since the 21st century. After joining the WTO, China integrated into the global electronic manufacturing chain and acted as the base for intermediate goods between the upstream and downstream of the industry, which promoted the exporting firms to increase the trade volume of the existing ICT products (Zhang et al. 2021).

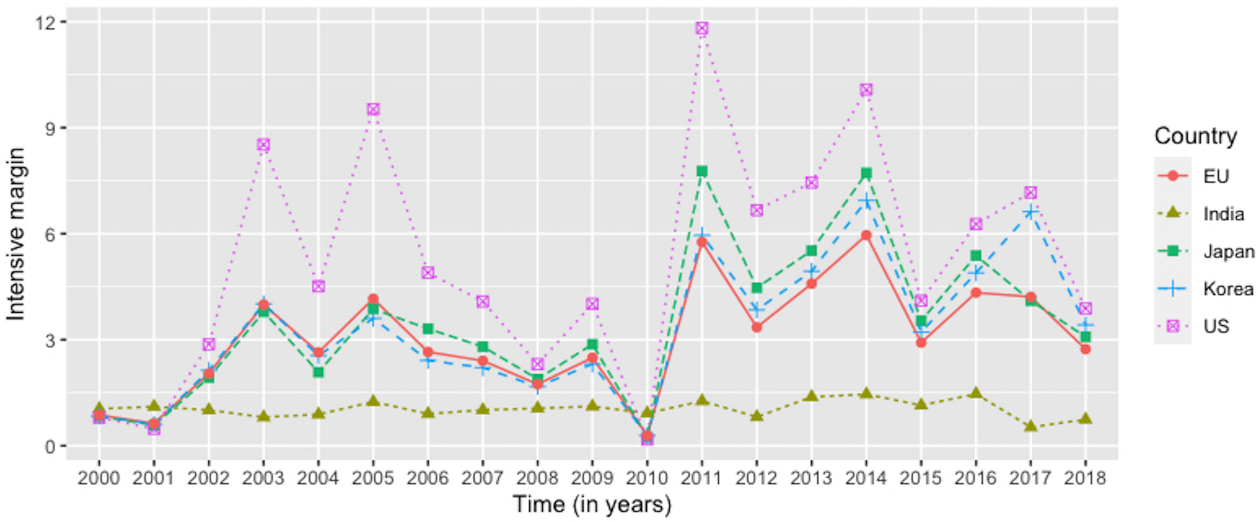

Figure 1. The intensive margins of ICT-products trade from China to the EU, the US, India, Japan and Korea from 2000 to 2018.

Figure 2 shows that extensive margins of China to Japan, South Korea, the US and the EU have decreased since 2000. This decline shows a limited contribution of the increase of product variety to the trade growth and the decreasing number of new Chinese ICT service developers, caused by the limited technological innovation and foreign capital redirection to Southeast Asian countries, which had much cheaper labour and land-rent costs from 2000 to 2018.

The cross-sectional study across countries is based on the comparison across the curves in Figures 1 and 2. Different shape of the curves indicates that China's trade growth depends on the development of the destination country. From 2000 to 2018, the dual margins of China to developing countries, particularly India, showed a stable and increasing trend.

This may be because China joined the WTO in 2001 and shared the benefit of exporting ICT products among members.

Second, the China–India–Myanmar Economic Corridor within the "One Belt and One Road" concept, proposed by China in 2013, has provided a favourable investment and trade environment. The variety of ICT products exported to developing countries and the number of Chinese firms that accept orders from foreign firms are increasing.

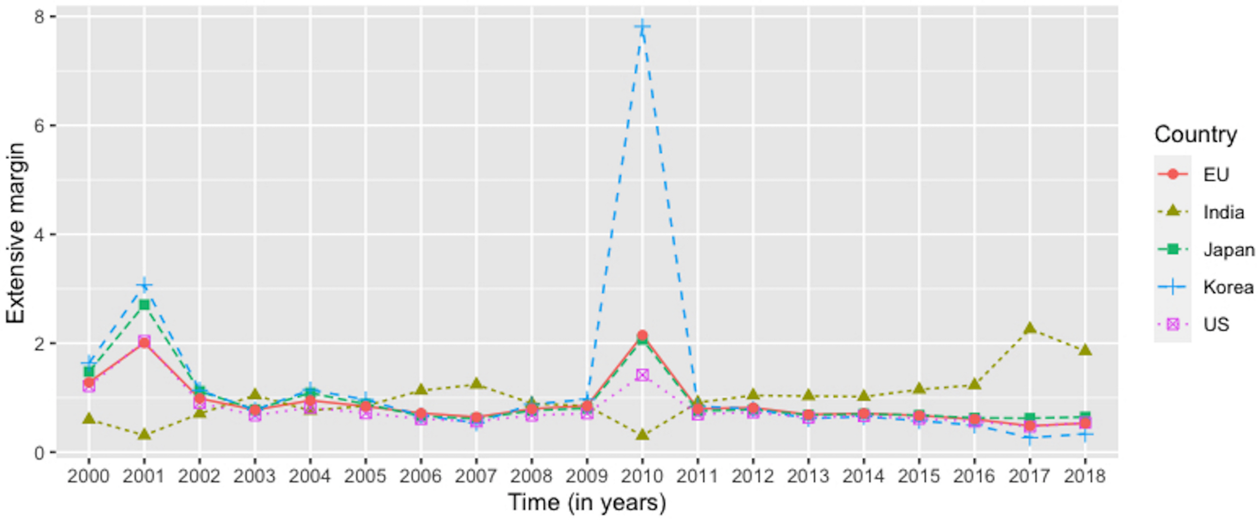

Figure 2. The extensive margins of ICT products traded from China to the EU, the US, India, Japan and Korea from 2000 to 2018.

Although the intensive margins of China's ICT products exported to developed countries, such as Japan, South Korea and the US, increased after 2000, they showed a large fluctuation, while the extensive margins showed a stable increase. In most years, the percentage of the extensive margin was smaller than the intensive margin. This indicates that China's ICT products exported to Japan, South Korea, the US and the EU were primarily driven by the intensive margin. The reason may be that, as mentioned in Williams et al. (2011), it remains a challenge for China's ICT products to satisfy all international technical standards, safety requirements and other technical barriers of trade (TBT) of developed countries. The diversity of China's ICT products exporting to developed countries remains a challenge.

However, in 2001 and 2010, the extensive margin was larger than the intensive of China's trade to developed countries. Before China joined the WTO, it may be of interest that it completed bilateral market access negotiations with South Korea, the US and Japan and the EU in 1997, 1999 and 2000, respectively. This promoted a rapid increase in the types of Chinese ICT products and the number of foreign-funded firms entering the Chinese market. Moreover, in 2010, the fixed trade costs, including labour and raw materials and the appreciation of RMB increased up to 28%, which resulted in the dramatic drop of ICT product exporting.

Specifically, according to the Electrical Appliances & Household Items Safety Control Act, South Korea began implementing a new Korea Certification (KC) system for electronic products beginning in July 2009. This system applies strict control over the electrical safety and circuit safety of electronic products. All electronic products must be certified with the KC Mark before being sold in the Korean market. As China's ICT products exported to South Korea were restricted by a TBT (i.e., the KC Mark), the export volume decreased dramatically. Thus, the number of export types (extensive margin) increased compared to the declined export volume (intensive margin).

4.2. Empirical Study

After the dual margins were obtained, factors were considered to have a large influence on the aggregate trade growth. To investigate how they may affect the trade growth, they were used as the independent variables in a local polynomial non-parametric regression of the dual margins. Comparing with the parametric fixed-effect model, this model is more flexible, as the influence of each factor on the dual margins can be investigated independently. The model is as follows.

$$\log IM_{odt} = f(\log L_{dt}, \log v_{od}, \log \theta_{dt}, \log \phi_{ot}, \log T_{odt}) + \mu_{odt} \tag{11}$$

$$\log EM_{odt} = f(\log L_{dt}, \log v_{od}, \log \theta_{dt}, \log \phi_{ot}, \log T_{odt}, \log C_{odt}) + \mu_{odt} \tag{12}$$

where the subscript odt represents the origin country o exports to the destination country d in year t. The intensive and extensive margins are included as the outcome variables in the model and denoted by IM and EM. The GDP to represent market size of the destination country in year t is involved as L_{dt}. According to Kancs (2007), as the variable trade cost can be estimated by the distance between the two parties, it is included by the geodesic distance between the capitals and denoted by v_{dt}.

Brkić et al. (2020) explained that the Index of Economic Freedom of Heritage Foundation indicates the international trade openness; therefore, we use it to represent the fixed trade cost and denote as C_{dt}. The labour force of the exporting country is denoted by ϕ_{dt} and the TBT in the destination country d from the exporting country o in year t is denoted by T_{odt} and the multilateral resistance θ is calculated using the trade freedom φ based on Head and Mayer (2004) as follows.

$$\theta_d = \sum_{r=1}^{R} \frac{L_r}{L} \varphi_{rd}, \quad \varphi = \sqrt{\frac{E_{od}E_{do}}{E_{oo}E_{dd}}} \tag{13}$$

where L denotes the market size of the destination country and E denotes the trade amount, and we assume there are R countries export to the destination country d. μ_{odt} denotes the random error.

This non-parametric fixed effect model for panel data used the local programming estimation (LPE) to estimate the coefficients, as introduced by Ullah and Roy (1998). Set

$$a_{odt} = (\log L_{dt}, \log v_{od}, \log \theta_{dt}, \log \phi_{ot}, \log T_{odt}) \tag{14}$$

$$b_{odt} = (\log L_{dt}, \log v_{od}, \log \theta_{dt}, \log \phi_{ot}, \log T_{odt}, \log C_{odt}) \tag{15}$$

Take the Taylor expansion of Equations (11) and (12) at the fixed points $x = a$ and $x = b$ as follows.

$$\log IM_{odt} = f(a_{odt}) + (a_{odt} - a)f'(a) + \epsilon_{IModt} \tag{16}$$

$$\log EM_{odt} = f(b_{odt}) + (b_{odt} - b)f'(b) + \epsilon_{EModt} \tag{17}$$

where ϵ_{odt} contains the rest of the Taylor expansion and the random error μ_{odt}. The components of $f'(x)$ are the partial derivatives of $f(x)$ at the components of x, which can be expressed by

$$f_i'(a) = \frac{\partial f(a)}{a_i}, \quad i = 1, 2, \ldots, 5; \quad f_i'(b) = \frac{\partial f(b)}{b_i}, \quad i = 1, 2, \ldots, 6 \tag{18}$$

Suppose the average $\log X_{odt}$ over time is denoted by $\log \overline{X}_{od}$, where X represents the any variables. The estimates of $f'(x)$ can be obtained by minimizing Equation (19).

$$\hat{f}'(x) = (\sum_{i=1}^{n} \sum_{t=1}^{T} (x_{odt} - \bar{x}_{od})^{\intercal} (x_{odt} - \bar{x}_{od})) K(\frac{x_{odt} - x}{h})^{-1} \tag{19}$$

where $K(g)$ is the kernel Gaussian function with bandwidth h. Following the choice of Ullah and Roy (1998), the optimal bandwidth formula is $h = cn^{-\frac{1}{14}}$ where n denotes the sample size and c is a positive constant. As the results are sensitive to the choice of bandwidth, c is selected by $c = 5.5$ based on repeated experiments.

Unlike the parametric model, the estimates are functions of the independent variables that represent their marginal effects on the outcome variables (dual margins). Table 2 shows the results of this non-parametric regression on dual margins, which indicate the following relationships. The increase in the market size of the destination country can bring a ten-fold increase in the intensive margin of China's export, which means the demand is a large promotion to the trade volume of existing ICT products. However, the increase of the distance between two trading parties may decrease up to 8% of the intensive margin.

The reason can be that a longer distance causes larger transporting costs, and firms have to reduce trade volume to control the fixed costs. The multilateral resistance of the destination country also has a negative effect on the intensive margin. If ICT products' global value chain framework is damaged, the destination country will face substantial resistance in trading with countries excluding China. This can cause decreasing demand for ICT products and decrease the export volume of upstream ICT products in China.

Table 2. Estimated coefficients of the regression based on different values of c.

Margins	Factors	c = 5	c = 5.5	c = 6
Intensive margin IM	market size L_d	11.06	11.11	11.27
	variable trade cost v_{od}	0.01	−0.08	−0.05
	multilateral resistance θ_d	−0.25	−0.27	−0.29
	labour force ϕ_o	4.75	−4.90	−5.11
	restriction of TBT T_d	−0.25	−0.24	−0.24
Extensive margin EM	market size L_d	10.98	11.33	11.67
	variable trade cost v_{od}	−2.52	−2.58	−2.80
	multilateral resistance θ_d	3.62	3.62	3.62
	labour force ϕ_o	−10.31	−10.74	−11.05
	restriction of TBT T_d	−0.28	−0.29	−0.28
	fixed trade cost C_{od}	−4.98	−4.95	−4.93

Another negative effect factor of the intensive margin is the labour productivity. Its increase will result in four times the decrease of the existing products trade volume. This indicates when China's labour productivity increases, firms tend to expand the trade to the products with better concessions and smaller risks instead of enlarging the trade of existing ICT products. As introduced in Bao and Qiu (2012), the TBT represents the level of technical rules and standards of the destination country, such as the material composition and patent technology. A higher level will enlarge the difficulty of exporting existing products.

The positive effect of the destination country's market size on the extensive margin also shows the potential efficiency of Chinese firms to adapt to the new global environment and challenges where they can increase the varieties to fit new global demands. Similar to the intensive margin, the distance between two trading parties has a negative effect on the extensive margin.

However, this indicates that Chinese firms prefer a conservative way to trade instead of increasing the trade varieties when the destination country is far away. The conservative rule are also followed when the labour productivity, level of technical standard and fixed trade costs increase. Moreover, China's exporting type of high-tech products can be limited when the destination country chooses to prevent its economy from importing products through high technological standards and expensive tariffs.

To further investigate the influence on the trade dual margins, we focus on the estimates in the non-parametric model, which are functions of the explanatory factors. By setting up a series values of the factor of interest and controlling other factors, the estimating results of the effects on intensive margin are shown in Figure 3. Except for the multilateral resistance of the destination country (top left), other factors show clear negative effects on the intensive margin where the TBT (middle) has the largest and stable influence. The reason can be the consistent rules that the destination country designates to a type (group) of ICT products. If the trade barrier becomes higher, the number of trade varieties that can satisfy this higher standard will dramatically drop.

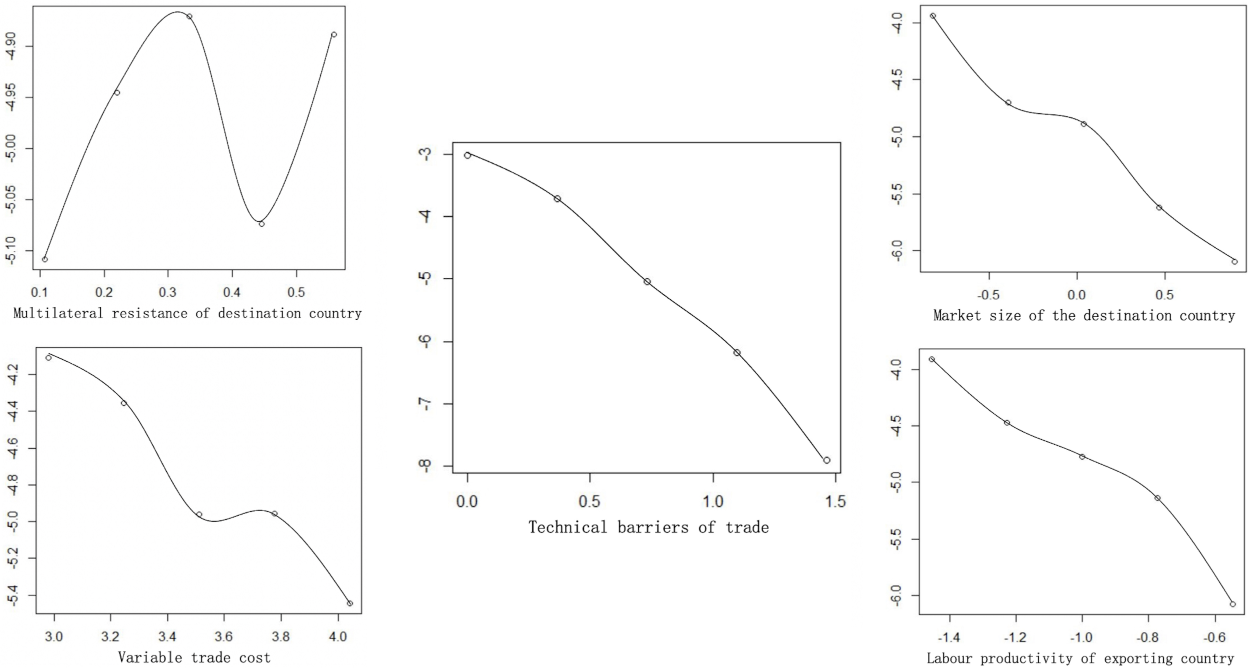

Figure 3. The dynamic estimation of effects on the intensive margin against each factor.

On the other hand, the estimating results of the effects on extensive margin are plotted in Figure 4. Both curves of the variable trade cost (top right) and the multilateral resistance of the destination country (top middle) show an increasing trend. At the same time, the rest still have negative effects on the extensive margin. This indicates that the distance between two trading parties and the multilateral resistance of the destination country has a limited negative effect on the development of new trade lines in China. Similar to the intensive margin, the technical barrier to trade is the primary factor in the decision to add new tradelines and the market size of the destination country.

In summary, from 2000 to 2018, the intensive margin increased while the extensive decreased. This indicates that the existing trade lines were developed; however, the increase of trade varieties was limited. Both dual margins contributed to the trade growth between China and other developing countries, such as India. However, the trade between China and developed countries, including Japan, Korea, the US and the EU, was conducted by the intensive margin or the existing trade lines' volume growth.

A larger market size of the destination country will promote the increase of the trade volume of the existing lines. However, the trade volume may decrease when the destination country is far away or has a high TBT. Even if the labour productivity of China increases, firms prefer developing domestic markets instead of international trade. Similarly, the extensive margin, or the number of trade varieties, tends to increase with the larger market size of the destination country and a larger difficulty for the destination country to trade. This can be evidence of the worldwide reputation of the ICT products.

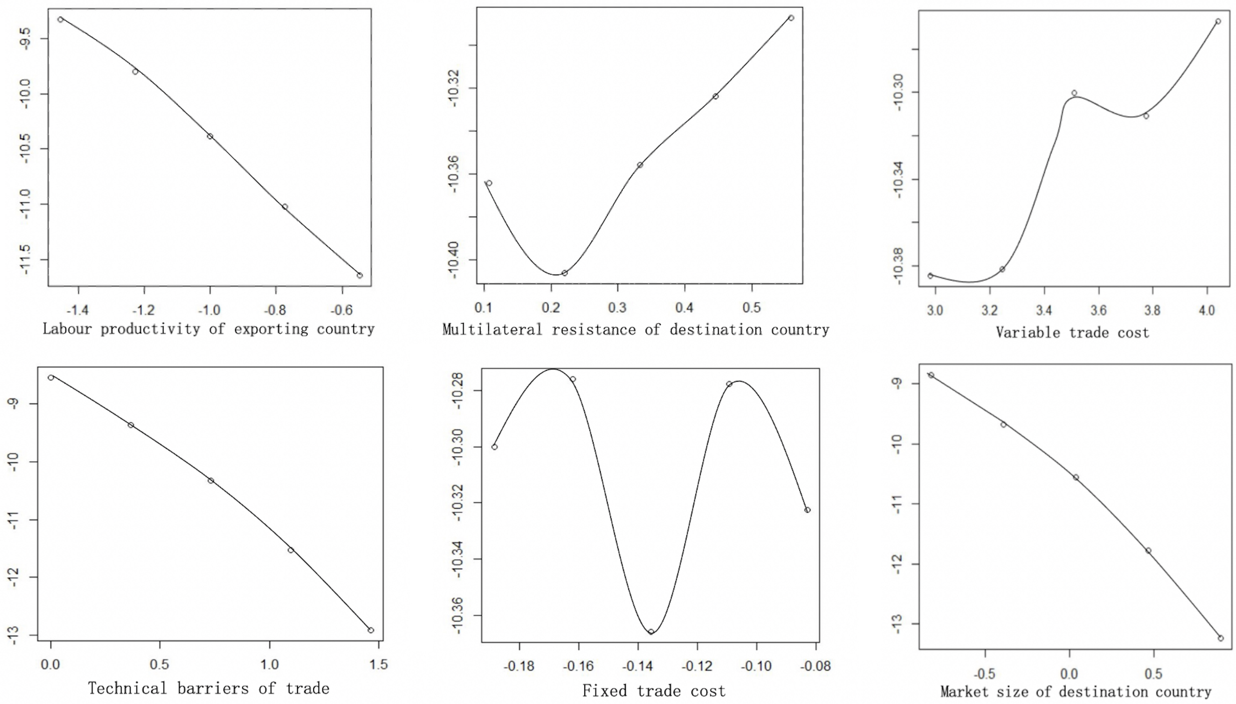

Figure 4. The dynamic estimation of effects on the extensive margin against each factor.

5. Discussion: Strategy and Policy Implications

Providing the empirical evidence in Section 4.2, we propose the following discussions and suggestions on strategies, which may be beneficial to the ICT trading in China. The main idea is to optimize the trading structure systematically so that the aggregate trade growth can increase.

The first is to reallocate the resource of the ICT industry so that the efficiency of resource consumption and the labour productivity can be maximized. On the one hand, the enterprises of ICT products can be classified into different batches. The ones with long-term trading lines and the potential to increase their market scale should be given priority to be developed, such as integrated circuits, program-controlled switches, mobile phones, colour TVs and other ICT products of inelastic demand.

In the meantime, firms with funding and strong research capabilities should be encouraged to investigate new trading lines or upgrade existing domestic lines to meet the international market demand. On the other hand, the policy of reducing the burden of exporting for firms should be implemented, such as reducing the taxes and fees for exporting ICT products and the cost of applying for the security certificate application, patent technology certification, etc. Optimizing the use of funding can help the firms increase the possibility of upgrading.

Second, open up the blocking points of international trade and transportation and complete the transportation chain according to the most recent national strategies. For example, to help firms build their chain based on the Belt and Road Initiative (BRI), proposed by Chinese President Xi Jinping in 2013. The plan and implementation of the transportation projects, including the New Eurasian Land Bridge and China–India Economic Corridor, can effectively break the trade barrier caused by the trade distance. This encourages firms to enlarge the transportation volume and increase the trading frequency. Another perspective is to pay attention to the quality of the storage warehouse for trading. Hardware facilities require an environment of moderate temperature, low humidity and high cleanliness. The improvements in tools, such as chain conveyor belts, foam vehicles and other non-vibrational transportation equipment, can reduce the risk of damage during the export and transportation of ICT products.

Moreover, the trading efficiency can be improved by creating a more convenient export environment for ICT products. On the one hand, the department of customs management can strengthen the linkage and cooperation to reduce unnecessary approval procedures and duplicate certificate inspections—for example, simplifying the procedures, including integrated circuit safety certification, metal content testing and intellectual property right (IPR) audits and creating a specific channel for products with radiation elements exceeding the standard.

On the other hand, it can be beneficial to implement a third-party acceptance mechanism to reduce trading costs. A competitive market for the IPR audit and equipment monitor will provide a cost-effective environment in trading. In the meantime, implementing an export subsidy policy and tax incentives can reduce storage and transportation costs.

Last but not least, the brand's reputation in ICT products is crucial for trading. Firms should be encouraged to implement a production-research mechanism. It is important to be familiar with the international technical regulations and standards to produce high-quality products. In addition, the government should play a macro-intervention role to provide official management of the supply chain, risk analysis for early warnings and the latest notification of technical trade barriers. They can also build their own standard that can fit into the international standard in cooperation with the country's top firms. Thus, the impact on the globalization body of ICT can be improved.

6. Conclusions

This study investigated economic development by decomposing the trade growth into intensive and extensive margins. A set of economic factors were considered to influence the decomposed trade growth. The empirical findings are based on China's ICT product trading data to India, Japan, South Korea, the US and the EU from 2000 to 2018. We conclude that China's strategy tends to be conservative. The trade varieties appear to drop when the variable and the fixed trade costs increase or the TBT becomes higher and the exporting labour productivity increases.

Chinese firms also prefer labour from the domestic market instead of developing new trade lines of ICT products to other countries. Thus, trade growth can benefit from the increase of labour productivity through a better structure of ICT industries and the trading environment of ICT products, the development of the quality of ICT products and enhancement of the international reputation of brands.

However, the sample in our study only covers limited numbers of developed and developing countries. This indicates that the findings may have bias because of certain countries that were not considered due to limited trading data or low percentages in the global markets. Future work can start from increasing the sample size or decomposing the trade growth of other products, such as the biomedical and the manufacturing sector. By comparing the decomposed trade growth in different industries, the investigation can be further developed based on the empirical studies of the factors that have a major impact on trade and economic development.

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Abbreviations

The following abbreviations are used in this manuscript:

BFTA	Bilateral Free Trade Area
CES	Constant Elasticity of Substitution
EM	Extensive Margin
GDP	Gross Domestic Product
HS	Harmonised System
ICT	Information and Communications Technology
IIC	Industrial Internet Consortium
IM	Intensive Margin
KC 2025	Korea Certification
MIC 2025	Made in China 2025
MIIT	Ministry of Industry and Information Technology
TBT	Technical Barriers of Trade
WCO	World Customs Organisation

References

Anderson, James E., and Eric van Wincoop. 2003. Gravity with gravitas: A solution to the border puzzle. *American Economic Review* 93: 170–92. [CrossRef]

Anderson, James E., and Eric van Wincoop. 2004. Trade Costs. *Journal of Economic Literature* 42: 691–751. [CrossRef]

Bao, Xiaohua, and Larry D. Qiu. 2012. How Do Technical Barriers to Trade Influence Trade? *Review of International Economics* 20: 691–706. [CrossRef]

Berke, Burcu. 2021. A Literature Survey on Extensive and Intensive Margins in International Trade. In *Impact of Global Issues on International Trade*. Pennsylvania: IGI Global, pp. 124–36. [CrossRef]

Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott. 2006. Trade costs, firms and productivity. *Journal of Monetary Economics* 53: 917–37. [CrossRef]

Berthou, Antoine, and Lionel Fontagne. 2011. The Euro and the Intensive and Extensive Margins of Trade: Evidence from French Firm Level Data. *SSRN Electronic Journal*. Available online: http://www.cepii.fr/PDF_PUB/wp/2008/wp2008-06.pdf (accessed on 20 May 2022).

Brkić, Ivana, Nikola Gradojević, and Svetlana Ignjatijević. 2020. The impact of economic freedom on economic growth? New european dynamic panel evidence. *Journal of Risk and Financial Management* 13: 26. [CrossRef]

Buchheit, Marcellus, Alex Ferraro, Chaisung Lim, Shi-Wan Lin, Jim Morrish, and Bassam Zarkout. 2020. Digital Transformation in Industry White Paper. *Industrial Internet Consortium*. Available online: https://www.iiconsortium.org/pdf/Digital_Transformation_in_Industry_Whitepaper_2020-07-23.pdf (accessed on 20 May 2022).

Cebeci, Tolga. 2012. *A Concordance among Harmonized System 1996, 2002 and 2007 Classifications (English)*. Washington, DC: World Bank Group.

Chaney, Thomas. 2008. Distorted gravity: The intensive and extensive margins of international trade. *American Economic Review* 98: 1707–21. [CrossRef]

Feenstra, Robert C. 1994. New product varieties and the measurement of international prices. *The American Economic Review* 84: 157–77.

Felbermayr, Gabriel J., and Wilhelm Kohler. 2006. Exploring the intensive and extensive margins of world trade. *Review of World Economics* 142: 642–74. [CrossRef]

Gereffi, Gary. 2014. Global Value Chains in a Post-Washington Consensus World. *Review of International Political Economy* 21: 9–37. [CrossRef]

Greenaway, David, and Chris Milner. 1983. On the measurement of intra-industry trade. *The Economic Journal* 93: 900–8. [CrossRef]

Hanson, Gordon, and Chong Xiang. 2011. Trade barriers and trade flows with product heterogeneity: An application to US motion picture exports. *Journal of International Economics* 83: 14–26. [CrossRef]

Head, Keith, and Thierry Mayer. 2004. Market Potential and the Location of Japanese Investment in the European Union. *The Review of Economics and Statistics* 86: 959–72. [CrossRef]

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein. 2008. Estimating Trade Flows: Trading Partners and Trading Volumes. *The Quarterly Journal of Economics* 123: 441–87. [CrossRef]

Horner, Rory. 2014. Strategic decoupling, recoupling and global production networks: India's pharmaceutical industry. *Journal of Economic Geography* 14: 1117–40. [CrossRef]

Hummels, David, and Peter J. Klenow. 2005. The variety and quality of a nation's exports. *American Economic Review* 95: 704–23. [CrossRef]

Institute for Security & Development Policy. 2018. *Made in China 2025: Backgrounder Report*. pp. 1–9. Available online: https://isdp.eu/content/uploads/2018/06/Made-in-China-Backgrounder.pdf (accessed on 20 May 2022).

Kancs, d'Artis. 2007. Trade growth in a heterogeneous firm model: Evidence from South Eastern Europe. *World Economy* 30: 1139–69. [CrossRef]

Madsen, Jakob B. 2001. Trade Barriers and the Collapse of World Trade During the Great Depression. *Southern Economic Journal* 67: 848–68. [CrossRef]

Madsen, Jakob B. 2009. Trade Barriers, Openness, and Economic Growth. *Southern Economic Journal* 76: 397–418. [CrossRef]

Magerman, Glenn, Karolien De Bruyne, and Jan Van Hove. 2013. Revealed Multilateral Trade Resistance in Gravity Models—A Network Approach. *The World Economy*, 1–33.

Melitz, Marc. 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71: 1695–725. [CrossRef]

Qian, Xuefeng, and Ping Xiong. 2010. The Dual Margin of China Export Growth and Its Determinants. *China Academic Journal Electronic Publishing House* 45: 65–79. [CrossRef]

Rana, Arun Kumar, and Sharad Sharma. 2021. *Industry 4.0 Manufacturing Based on IoT, Cloud Computing, and Big Data: Manufacturing Purpose Scenario*. Singapore: Springer, vol. 668. [CrossRef]

Sen, Sunanda. 2010. International trade theory and policy: A review of the literature. Levy Economics Institute Working Papers Series No. 635, Levy Economics Institute, Annandale-On-Hudson, NY, USA.

Singh, Tarlok. 2010. Does international trade cause economic growth? A survey. *World Economy* 33: 1517–64. [CrossRef]

Sohag, Kazi, Rawshan Ara Begum, Sharifah Mastura Syed Abdullah, and Mokhtar Jaafar. 2015. Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia. *Energy* 90: 1497–507. [CrossRef]

Ullah, Aman, and Nilanjana Roy. 1998. *Nonparametric and Semiparametric Econometrics of Panel Data*. Boca Raton: CRC Press. [CrossRef]

Van Assche, Ari, and Byron Gangnes. 2010. Electronics production upgrading: Is china exceptional? *Applied Economics Letters* 17: 477–82. [CrossRef]

Williams, Robin, Ian Graham, Kai Jakobs, and Kalle Lyytinen. 2011. China and global ict standardisation and innovation. *Technology Analysis & Strategic Management* 23: 715–24. [CrossRef]

Yang, Chun, and Canfei He. 2017. Transformation of China's 'World Factory': Production Relocation and Export Evolution of the Electronics Firms. *Tijdschrift voor Economische en Sociale Geografie* 108: 571–91. [CrossRef]

Zameer, Hashim, Humaira Yasmeen, Muhammad Wasif Zafar, Abdul Waheed, and Avik Sinha. 2020. Analyzing the association between innovation, economic growth, and environment: Divulging the importance of FDI and trade openness in India. *Environmental Science and Pollution Research* 27: 29539–53. [CrossRef]

Zhang, Hongsheng, Yueling Wei, and Shuzhong Ma. 2021. Overcoming the "solow paradox": Tariff reduction and productivity growth of chinese ict firms. *Journal of Asian Economics* 74: 101316. [CrossRef]

Zhang, Meilan, and Lianxing Yang. 2021. How has the dual margin of cultural trade affected the added value of cultural products export. *Collected Essays on Finance and Economics* 274: 3–13.