

Nexus of Technology Adoption, E-commerce, and Global Value Chains: The Case of Asia

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Existing literature has examined either the key drivers of global value chain (GVC) exports or the factors affecting e-commerce growth. Studies that investigate the impact of e-commerce, in particular business-to-consumer (B2C) e-commerce, on GVCs are largely missing. The growing prevalence of digital platforms centered around e-commerce marketplaces motivates this study to examine if e-commerce growth in an economy can affect its GVC exports and how information and communication technology infrastructure and technology adoption measures, payment systems, and delivery mechanisms can facilitate this growth. Panel ordinary least squares, feasible generalized least squares, and two-stage least squares estimations are used to determine the relationship between GVC exports and e-commerce sales. The results indicate empirical evidence of the positive impact of B2C e-commerce on GVC exports. The robust and positive impact of B2C e-commerce on GVC exports—when instrumented by secure internet servers, internet bandwidth, and digital payment schemes—suggests growth of B2C e-commerce in an economy can contribute to its GVC participation.

Keywords: digital payment, e-commerce, GVC, ICT infrastructure

JEL codes: C13, E21, F14

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I. Introduction

Global value chain (GVC) exports have characterized the landscape of the global division of labor and fragmentation of production stages across borders.¹ At the same time, the rapid progress of the digital economy enables businesses and consumers to interact through digital platforms, in particular e-commerce platforms, and engage in real-time commercial transactions with an extraordinary level of efficiency and mass volumes. While various factors, such as the growing role of multinational enterprises' efficiency-seeking foreign direct investment (FDI) and the cost-effectiveness of outsourcing and offshoring production strategies being adopted by various firms, have been investigated extensively, and the factors affecting the rapid expansion of e-commerce marketplaces analyzed, little study has been undertaken to examine the impact of e-commerce on the growth of GVC exports. Conceptually, e-commerce, in particular business-to-business (B2B) e-commerce, should contribute to the expansion of GVC exports by reducing search, matching, communications, and logistics costs, thereby facilitating flows of intermediate goods and services across borders at lower costs for both buyers and sellers. Whether business-to-consumer (B2C) e-commerce, which directly connects buyers and consumers in domestic and foreign markets, can also contribute to GVC exports remains largely an empirical question to be tested.²

Most studies have only explored the factors affecting GVCs and those influencing e-commerce transactions, yet studies that investigate the impact of e-commerce on GVCs, in particular through the linkages of information and communication technology (ICT) infrastructure and technology adoption measures, are largely missing. This paper aims to fill the literature gap through an empirical investigation of the nexus between technology adoption, GVCs, and B2C online sales, particularly internet retail and mobile commerce (m-commerce) sales, by asking the following research questions: Does the growth of B2C e-commerce affect GVC exports? And do technological factors affecting e-commerce growth underpin the relationship between B2C e-commerce and GVC exports?

Advances in internet connectivity and ICT have driven the decline in trade-related information and communications costs. The internet reduces information asymmetry and has revolutionized the relationship between manufacturers, retailers, and consumers in terms of the substance and spread of information. By utilizing

¹GVC refers to international production sharing whereby production stages are distributed across borders in different economies.

²B2C refers to businesses selling products to consumers directly instead of relying on wholesale and retail intermediaries.

innovations available through the internet and Web multimedia capacities, firms can easily produce content that provides specific product information tailored to a particular consumer group. Hence, the internet creates opportunities for firms to generate revenues in novel ways by adding more value to existing goods and services, or by laying the groundworks for new products and services.

The proliferation of digital platforms such as Amazon, Alibaba, and Lazada, which have given rise to a platform-based economy, reduces the initial fixed costs associated with GVC participation by providing venues for buyers and sellers to connect with each other in high-value exchanges that blend products and services (Li, Frederick, and Gereffi 2019; Antràs 2020). Digital platforms play a crucial role in bridging online purchasers and producers by enabling direct interactions and reducing information asymmetry. As a result, digital platforms create positive spillover effects by generating value not only for themselves but also for consumers and producers.

Engaged consumers and social commerce reduce the marketing and advertisement costs of sellers because consumers themselves promote the products through product reviews, customer satisfaction ratings, and social commerce engagements such as retweets, shares, or likes in various social media platforms including Meta (rebranded from Facebook), Twitter, and Instagram. E-commerce helps firms overcome the difficulties of accessing buyers, including the financial burden of physically opening stores and paying for expensive advertisement campaigns (Li, Frederick, and Gereffi 2019).

Firms can gather a substantial amount of consumer feedback through ratings and comments about the products sold. This feedback is available in real time through online live streaming, which incentivizes manufacturers to improve product development and diversify their product offering in response to consumer feedback. As a result, digital platforms can provide consumers with a means to actively engage in value chains, creating new opportunities for GVC expansion and upgrading, resulting in higher GVC exports. Technological innovations—such as internet access, payment systems for online consumption, and delivery systems—are the key factors that make it possible for consumers and firms to engage in the online marketplace. A reliable ICT infrastructure with far-reaching internet access underpins this interlinkage.

The nexus between GVCs, technological innovation, and e-commerce or digital platforms is, as made clear, compelling. A key implication of this nexus is that as economies become increasingly reliant on digital solutions, GVCs, e-commerce, and technology can no longer be perceived as mutually exclusive trends and forces.

A dearth of empirical studies, however, investigates how the tripartite forces of GVCs, e-commerce, and technology interact with each other. Asian economies are deeply involved in GVCs relative to other regions and have massive untapped market potential in online retailing. Nevertheless, there is a lack of empirical investigation into the interrelationship between GVCs and e-commerce in Asia.

Drawing upon the analytical framework developed by Gereffi, Humphrey, and Sturgeon (2005), which presents a GVC typology and mechanism of value chain transformation, Inomata (2017) considered the impact of new technologies on the organization of GVCs. Looking in particular at two representative industries—automotive and electronic equipment—demonstrates that the novel characteristics of production technology that include modularization and platforms may induce changes in the existing structure of value chains, allowing new firms to participate. For this to happen, the study recommends engaging lead firms from advanced economies in implementing the learning strategies, which can have a significant effect on developing economies aiming for sustainable economic growth by moving up the value chain.

From a futuristic perspective, Strange and Zucchella (2017) identified four new digital technologies under “Industry 4.0”: (i) the Internet of Things (IoT), (ii) big data and analytics, (iii) robotics, and (iv) 3D printing. The study explores the possible disruptive impact of Industry 4.0 on the existing configurations of location and control within GVCs.³ The IoT, which uses sensors in monitoring products or inventories to generate real-time data, among other things, is expected to revolutionize the coordination of geographically dispersed value chains by substantially reducing the transaction costs of cross-border production. The IoT assigns products with unique identifiers linking them to information about their origin, use, and final destination, thereby integrating the monitoring of two separate flows: physical products and information. Because of this new technology, Strange and Zucchella (2017) conjectured that the IoT will substantially benefit production and distribution efficiency, especially because GVCs involve the cross-border movement of goods.

Lanz et al. (2018), using firm-level data from the World Bank’s Enterprise Survey, found robust evidence of a positive impact on GVC participation among the manufacturing small and medium-sized enterprises (SMEs) arising from digital connectivity, in both backward and forward linkages. SMEs with an online presence

³Industry 4.0 refers to the transition of the manufacturing sector toward more digitally driven and “smart” methods of production utilizing computerization and digital technologies.

through a website are found to be more actively engaged in GVCs. For them, imports comprise a larger share of their inputs for production, while exports account for a higher ratio of their sales than for SMEs that do not have an online presence.

These findings are consistent with Xing (2018), who examined the impact of the internet and e-commerce adoption on bilateral trade, as measured by total exports, for a panel of 21 developing and least-developed economies and 30 Organisation for Economic Co-operation and Development economies. The empirical results show that enhanced access to modern ICT and the adoption of e-commerce platforms facilitate bilateral exports. However, the estimation technique used in this study fails to account for the possible endogeneity of the e-commerce variables.

This study employs panel ordinary least squares (OLS) and feasible generalized least squares (FGLS) estimations to investigate the impact of B2C e-commerce sales (i.e., internet retail sales and mobile internet retail sales) on GVC exports. A two-stage least squares (2SLS) estimation technique is also used to minimize potential endogeneity arising from the omitted variables. For this, instruments on technology adoption and financial environment readiness are employed. The results indicate strong empirical evidence of the positive impact of B2C online commerce on GVC exports. ICT infrastructure—in the form of international internet bandwidth, technology adoption measures (i.e., internet access and secure server penetration), and financial infrastructure—is found to drive e-commerce sales, thereby influencing the GVC exports of an economy.

This paper is structured as follows. After the introduction, Section II discusses the conceptual framework by focusing on the factors affecting GVC exports and e-commerce sales. Section III presents the data, estimation techniques, and regression results for OLS, FGLS, and 2SLS. Section IV concludes.

II. Conceptual Framework

This section illustrates potential economy-level factors that drive GVC and B2C e-commerce. Previous studies, including Urata and Baek (2020), identified economy-level characteristics that affect GVC exports such as trade openness, FDI, and logistics. Li, Frederick, and Gereffi (2019) investigated how e-commerce stimulates GVC exports by reducing barriers to entry. Ho, Kauffman, and Liang (2011) examined the impact of ICT connectivity and financial infrastructure on e-commerce revenues. Building on these findings and linking the identified channels, this study considers B2C e-commerce as a potential factor impacting GVC exports.

A. Economy-level Determinants of GVC Exports

1. Income of Importing Economies

Stylized facts in macroeconomics and existing literature on international trade identify the growth of income of importing economies as the most important factor driving the exports of exporting economies. Rising incomes in importing economies drive the consumption of foreign goods, thereby creating more demand for exports. Given that official income data only capture the degree of import demand through traditional trade linkages—failing to reflect import demand through the cross-border, industrial input–output linkages of GVC channels—we introduce the GVC-weighted income of an importing economy relative to an exporting economy as a proxy for the measurement of import demand.

2. International Trade and Foreign Direct Investment

International openness pertains to the extent to which an economy is open to business and economic activities through international trade. On the one hand, import restrictions such as tariff protections make procurement of inputs to production burdensome, thereby reducing the incentive to export (Kowalski et al. 2015). On the other hand, involvement in preferential trade agreements is found to increase GVC exports (Ignatenko, Raei, and Mircheva 2019). Openness to FDI promotes GVC exports because a liberal FDI regime incentivizes multinational companies to invest and expand GVCs (Kowalski et al. 2015), which is more apparent with multinational companies seeking efficiencies through vertical (instead of horizontal) investments in host economies.

3. Logistics

Efficiency in logistics is the backbone of the complex system of GVC networks. The development and proliferation of GVCs have been driven by advancements in modern logistics services made possible by innovations in containerization, intermodal transport, and the application of ICT in physical distribution and materials management (Memedovic et al. 2008). Efficient and reliable logistics significantly reduce the cost of participation in GVCs, allowing multinational companies to develop a complex network of GVCs that maximize their gains by shortening delivery times. Kowalski et al. (2015) lent empirical support to this narrative in finding that high logistics performance in customs increases GVC exports.

4. E-commerce

The rapid growth of e-commerce is creating more opportunities for GVC expansion. Digital platforms and facilities such as digital payment systems and logistics have driven the explosive growth of e-commerce. This gives firms direct access to international and domestic commerce. In recent times, business operations have relied on internet-based systems that merge data and information across roles and locations. The integration of e-procurement, demand and supply forecasting, and e-logistics, which underpins the development of e-commerce, makes them digitally powered and knowledge-intensive. This reduces the transaction costs of cross-functional, cross-location, and cross-company cooperation, enabling frictionless integration and collaboration and easier access to market information and marketing resources. This development has also caused cross-border e-commerce to be more fragmented, allowing for the diversification of imports and exports along GVCs. For instance, e-commerce can lead to product diversification while reducing the inventory required in a physical store or warehouse. Overall, innovations in online commerce create an impetus for GVC growth, and this trend is expected to continue over the next decade. While plausible, the impact of e-commerce, in particular B2C, on GVC remains an empirical question to be tested.

B. Factors Affecting E-commerce Revenue: ICT Connectivity and Financial Infrastructure

Technological advancement in ICT and financial payment infrastructure are two key pillars directly supporting B2C e-commerce, without which online transactions—including through browsing, ordering, payment, tracking, and reviewing—would not be available.

1. Digital Connectivity

Internet users are a key indicator of internet connectivity, influencing the market size of e-commerce and characterizing individual-level technology adoption. Internet users generate value through network externalities from their use of B2C e-commerce mechanisms. Meanwhile, secure servers are the relevant technology infrastructure supporting the supply side of e-commerce because they facilitate safe online transactions through the encryption of credit card transactions during the online payment process. This reduces transaction risks and strengthens the trust between vendors and buyers. Secure servers lay the groundwork for e-business infrastructure.

The number of secure servers represents firm-level initiatives to supply secure internet retailing services to the market and adopt internet-based selling technology (Ho, Kauffman, and Liang 2011). Secure socket layer is used by online retailers, online banking and financial services, and other internet service providers to ensure the encrypted transfer of information between servers and browsers. This way, secure servers protect sensitive information such as credit card and personal details by ensuring that these can be encrypted and transmitted securely over the internet. Greater availability of online shops and secure online transactions encourage more people to shop online, which generates more B2C e-commerce revenues.

2. Internet Bandwidth

International internet bandwidth serves as a measure of the quality and speed of ICT infrastructure. Bandwidth is the backbone of all e-commerce. It is the measurement of data transfer capacity between a user's connection and the internet, and each website has its own bandwidth capacity. Higher bandwidth translates to faster information accessibility for e-commerce customers. Low bandwidth does not only affect load time but also has implications on the number of potential customers that can view the e-commerce site's information.

3. Digital Payment

Financial card penetration denotes the readiness of financial infrastructure to support online transactions. The availability of financial resources that consumers can use in e-commerce transactions is a key factor to support online commercial transactions without having to engage in face-to-face cash payments. Financial cards, both debit and credit, have been identified as one of the important alternative payment tools that support B2C e-commerce growth in many Asian economies. Kang, Wang, and Ramizo (2021) showed a close relationship between B2C online commerce and financial readiness indicators. The study finds strong empirical evidence on the positive impact of debit card penetration on all segments of B2C online sales.

4. International Openness

Technology diffusion, or the transfer of technological knowledge among economies, is an important factor affecting the development of e-commerce. Several studies have considered trade or international openness as an exogenous and external factor that represents knowledge spillovers from economies that have positive contributions to the technical progress of trade partners and technology diffusion

among economies (Grossman and Helpman 1991; Coe and Helpman 1995; Coe, Helpman, and Hoffmaister 1997; Keller 1998). International openness can be estimated based on the ratio of the sum of exports and imports to gross domestic product (GDP) (Ho, Kauffman, and Liang 2011). FDI as an openness mechanism to generate technology spillovers has also been identified and investigated in previous literature. Multinational enterprises in industrialized economies have advanced technology, extensive product diversification, and greater management proficiency (Markusen 1995, Caves 2007). As a result, advanced economies have implemented regulations and incentive schemes to attract FDI with the goal of creating positive spillover effects.

5. Logistics

The delivery of goods to customers is a crucial aspect of e-commerce. Efficient and frictionless transport of goods is imperative for both domestic and cross-border e-commerce. Well-functioning road transport, ports, postal delivery services, and customs are key components of the effective delivery of goods ordered online. Inefficiencies in the logistics system—covering freight transportation, warehousing, border clearance, and domestic postal delivery—worsen the trade costs of firms involved in e-commerce. Hence, maximizing the positive impacts of transport and logistics to e-commerce could also result in higher efficiencies along the logistics chain. These measures comprise, among others, modernizing urban freight logistics, building infrastructure to connect urban and rural areas, and facilitating freight flows between warehouses (or consolidation centers) and consumption nodes. Constructing multimodal links and transit regimes for the improvement of corridor efficiency could also alleviate transport costs along the logistics chain and hasten delivery (Rodriguez 2018).

III. Data, Methods, and Empirical Analysis

This section discusses the research methodology, data sources, and operational definitions of the selected variables for empirical analysis and presents the results. Panel OLS and FGLS are used to assess the effects of e-commerce revenues on GVC exports. Further, a 2SLS model is employed to determine the impact of e-commerce revenues on GVC exports to address the potential endogeneity problem associated with omitted variable bias while capturing the indirect effects of e-commerce determinants (i.e., technology adoption measures and financial infrastructure) on GVC exports.

A. Data and Variables

To empirically implement the estimation techniques and examine the impact of e-commerce revenues on GVC exports, secondary data are derived from the International Telecommunication Union, World Development Indicators, the United Nations Conference on Trade and Development, International Monetary Fund, and national sources. Data are also gathered from proprietary databases including CEIC, Haver Analytics, and Euromonitor International, Retailing Industry Edition 2019, where we obtain a dataset on B2C online commerce sales that is comparable across economies and years. GVC indicators are generated using the gross export decomposition methodology of Wang, Wei, and Zhu (2014) and the Asian Development Bank Multiregional Input–Output Table (Table 1).

Internet retailing is defined as sales of consumer goods to the general public through the internet, including those from mobile phones and tablets (Euromonitor International, Retailing Industry Edition 2019). The scope of sales includes transactions arising from pure e-commerce websites and those operated by store-based retailers. This also covers Web-based transactions for which the payment is then made through a store card, an online credit account subsequent to delivery, or on delivery of the product. Modes of payments cover postal cheque, direct debit, standing order, and other banking tools, as well as orders paid for with cash on delivery. However, click-and-collect orders, where the payment is made in the store, are excluded.

The definition of internet retailing used in this study covers a wide selection of products from apparel and footwear, pet care products, and home furnishings to video game hardware (Euromonitor International, Retailing Industry Edition 2019). However, several other types of merchandise fall outside this definition such as motor vehicles; motorcycles and vehicle parts; tickets for events (e.g., sports, music concerts, and travel); travel and holiday packages; revenue generated by online gambling sites; quick delivery services of food, magazines, and household goods; and DVD rentals such as Netflix, among others. Mobile internet retailing, or m-commerce, sales are transactions through mobile devices such as smartphones and tablets. These transactions also fall under internet retailing. Sales data follow the place of origin of the consumer instead of the location of the seller. Moreover, sales are limited to B2C online sales and exclude consumer-to-consumer transactions such as e-Bay. Detailed data descriptions are provided in Table 1.

The study covers 14 Asian economies from 2007 to 2019: (i) the People’s Republic of China (PRC), (ii) Indonesia, (iii) India, (iv) Japan, (v) Kazakhstan, (vi) Cambodia, (vii) the Republic of Korea, (viii) the Lao People’s Democratic

Table 1. **Modeling Variables, Operational Definitions, and Data Sources**

Variable	Operational Definition	Data Source
GVC Exports	Include domestic value-added absorbed abroad, domestic value-added returns home, and foreign value-added	Asian Development Bank
Internet Retail Sales	Sales of consumer goods to the general public through the internet, including those from mobile phones and tablets	Euromonitor International
Mobile Internet Retail Sales	Also called m-commerce sales, these are the transactions through mobile devices such as smartphones and tablets. These transactions also fall under internet retailing	Euromonitor International
Trade Openness	(Exports + Imports)/GDP	World Bank
FDI (% of GDP)	FDI share (inward FDI stock as a percentage of GDP)	United Nations Conference on Trade and Development and World Development Indicators
Debit Card Penetration ^a	Number of debit cards per 1,000 adults	International Monetary Fund
Server Penetration	Secure internet servers (per 1 million people)	World Bank
International Internet Bandwidth	Total capacity of international internet bandwidth in mega bits per second (Mbit/s). It is measured as the sum of used capacities of all internet exchanges (locations where the internet traffic is exchanged) offering international bandwidth	International Telecommunication Union
Internet Penetration	Individuals using the internet (percentage of population)	World Bank
Logistics Performance Index (LPI) Score	LPI indicates the quality of trade and transport-related infrastructure (from 1 = low to 5 = high)	World Bank

FDI = foreign direct investment, GDP = gross domestic product, GVC = global value chain.

^aGiven that credit card data are highly correlated with other technology variables, we consider the debit card data only.

Source: Authors' compilation.

Republic, (ix) Malaysia, (x) Pakistan, (xi) the Philippines, (xii) Singapore, (xiii) Thailand, and (xiv) Viet Nam. Economy coverage is limited by the availability of data across various secondary sources. The availability of B2C online commerce data covering selected Asian economies varies across years. Data availability for internet retail sales starts from 2004, while the mobile Internet retail sales data are available from 2011 (Table 2).

Table 2. Descriptive Statistics

Variable	Mean	Minimum	Maximum	Standard Deviation
Internet Retail Sales	4.66E + 07	4,253	1.17E + 09	1.58E + 08
Mobile Internet Retail Sales	3.22E + 07	0	1E + 09	1.31E + 08
GVC-weighted Income	1.608	0.628	2.625	0.499
Trade Openness	1.142	0.283	4.426	1.101
FDI (% of GDP)	85.301	3.311	569.656	147.536
Debit Card Penetration	1,623.429	187.988	7,087.186	187.988
Server Penetration	5,020.920	0.796	128,377.7	18,308.23
International Internet Bandwidth	7,461,806	5,000	1.14E + 08	1.66E + 07
Internet Penetration	57.900	8	96.505	27.044
LPI Score	3.274	2.395	4.143	0.513

FDI = foreign direct investment, GDP = gross domestic product, GVC = global value chain, LPI = Logistics Performance Index.

Source: Authors' calculations.

B. Model Diagnostics

Panel observations that include time-series data can introduce potential problems of serial correlation between successive years of the data. Another concern is endogeneity, which is a usual problem in cross-economy analysis. Several diagnostic tests were undertaken to examine multicollinearity, serial correlation, and endogeneity. First, a pair-wise correlation analysis was performed to ensure that no two variables were highly correlated, making both of them ineffective as regressors. The pair-wise correlation coefficients between the explanatory variables were all lower than 0.8 except for (i) trade openness and FDI stock; and (ii) secure server and internet penetration. As a result, these variables cannot be estimated in one model (Table 3). Postestimation tests on serial correlation and endogeneity are discussed in the succeeding subsections.

C. Panel Ordinary Least Squares and Feasible Generalized Least Squares Estimations

The estimation model includes factors identified in the conceptual framework as affecting the GVC exports of economy i at time t with the year fixed effects $year_t$ and error term ε_{it} :

$$\begin{aligned} \ln GVC_{it} = & \delta_0 + \delta_1 \ln B2C_{it} + \delta_2 \ln GWI_{it} + \delta_3 \ln LPI \text{ Score}_{it} \\ & + \delta_4 \ln \text{International Openness}_{it} + \delta_5 year_t + \varepsilon_{it}, \end{aligned} \quad (1)$$

Table 3. Correlations between the Main Variables in the Study

Variables	Internet Retail Sales		Mobile Internet Retail Sales		GVC-weighted Income		Trade Openness (% of GDP)		FDI (% of GDP)		Debit Card Penetration		Server Penetration		International Internet Bandwidth		Internet Penetration		
	Internet Retail Sales	1	Mobile Internet Retail Sales	1	GVC-weighted Income	1	Trade Openness (% of GDP)	1	FDI (% of GDP)	1	Debit Card Penetration	1	Server Penetration	1	International Internet Bandwidth	1	Internet Penetration	1	
Internet Retail Sales	1																		
Mobile Internet Retail Sales	0.947***	1																	
GVC-weighted Income	0.140**	0.236***	1																
Trade Openness	-0.007	-0.153*	-0.162***	1															
FDI (% of GDP)	-0.114**	-0.241**	-0.500***	0.822***	1														
Debit Card Penetration	0.731***	0.606***	0.166***	0.184***	-0.097	1													
Server Penetration	0.593***	0.432***	0.311***	0.296***	0.365***	0.534***	1												
International Internet Bandwidth	0.829***	0.705***	-0.016	-0.056**	0.236***	0.404***	0.567***	1											
Internet Penetration	0.683***	0.250***	0.110***	0.314***	0.285***	0.570***	0.828***	0.693***	1										
LPI Score	0.655***	0.629***	-0.058	-0.084***	0.048	0.079***	0.044**	0.018	0.016	1									

FDI = foreign direct investment, GDP = gross domestic product, GVC = global value chain, LPI = Logistics Performance Index.

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Source: Authors' calculations.

where $B2C_{it}$ = Internet Retail Sales_{*it*}, Mobile Internet Retail Sales_{*it*},⁴ and International Openness_{*it*} = Trade Openness_{*it*}, FDI_{*it*}.

The GVC-weighted Income (GWI_{*it*}) for the exporting economy *i* refers to the GDP of the destination economy *j* weighted by the share of GVC exports from economy *i* and economy *j* at year *t* as follows:

$$GWI_{it} = \sum_{j=1}^n \frac{GVC_{jit} Y_{jt}}{GVC_{it}}, \quad i \neq j, \quad (2)$$

where GVC_{jit} is the GVC exports of home economy *i* to destination economy *j* at year *t* in a common currency (US dollar). GVC_{it} is the total GVC exports of economy *i* in common currency, and Y_{jt} is the real income of destination economy *j*. The World Bank's World Development Indicators database is the source of real income (real GDP) data. For each economy, it is normalized to have a mean of 1 across time periods. This variable is included to capture global economic mass and as an index for the market potential of the home economy's GVC exports.

Standard assumptions underlying OLS regressions are often violated in empirical research using panel data. Postestimation tests are conducted to determine the presence of serial correlation. While serial correlation does not lead to a biased or inconsistent OLS estimator, it results in inefficiency. A Wooldridge test is implemented to check for autocorrelation in the panel data. The *p*-values of the *F*-statistics of the Wooldridge test show that there is first-order correlation in the residuals of Models 1 and 5 of Table 4, and in Models 1 and 3 of Table 5. AR(1) autocorrelation is characterized by an error term in one time period that is proportional to the disturbance in the previous time period, including a spherical disturbance. This is expected because some variables—such as B2C e-commerce revenues (i.e., Internet Retail Sales and Mobile Internet Retail Sales), Logistics Performance Index (LPI) Score, Trade Openness, and FDI—may exhibit comovement across periods.

To address the presence of autocorrelation in the residuals, an FGLS regression is implemented to address the serial correlation of the errors. FGLS regression takes into consideration that the errors are serially correlated, usually as an AR(1) process, and imposes the assumption that the variance–covariance matrix of the errors is unknown. Hence, standard error estimates are robust to disturbances being heteroscedastic,

⁴Given the prevalence of mobile retail sales in the e-commerce marketplace, which is unique in many developing economies in Asia, we also examine the channel through mobile retail sales as a subset of internet retail sales. Due to smaller sample size, however, we cannot conduct a 2SLS exercise to test the impact of mobile retail sales on the GVC exports.

Table 4. Regression Results of Panel Ordinary Least Squares, Feasible Generalized Least Squares, and Two-stage Least Squares

	Dependent Variable: $\log(\text{GVC Exports})_{it}$							
	Model 1 Panel OLS	Model 2 FGLS	Model 3 2SLS	Model 4 2SLS	Model 5 Panel OLS	Model 6 FGLS	Model 7 2SLS	Model 8 2SLS
$\log(\text{Internet Retail Sales})_{it}$	0.195*** (0.0664)	0.348*** (0.022)	0.591*** (0.0303)	0.554*** (0.0174)	0.210*** (0.0669)	0.340*** (0.022)	0.581*** (0.0289)	0.535*** (0.0168)
$\log(\text{GVC-weighted Income})_{it}$	-0.332 (0.245)	-0.138** (0.059)	-0.724*** (0.0986)	-0.587*** (0.0849)	-0.496* (0.259)	-0.151** (0.058)	-0.643*** (0.0874)	-0.496*** (0.0829)
$\log(\text{LPI Score})_{it}$	0.459 (0.417)	0.631** (0.284)	-0.898 (0.569)	-0.124 (0.373)	0.667 (0.585)	0.760** (0.280)	-0.0748 (0.501)	0.844*** (0.31)
$\log(\text{Trade Openness})_{it}$	0.775*** (0.289)	0.209** (0.086)	0.492*** (0.0591)	0.463*** (0.0473)				
$\log(\text{FDI (\% of GDP)})_{it}$					-0.0143 (0.142)	-0.280*** (0.073)	0.323*** (0.0365)	0.299*** (0.0291)
Constant	8.411*** (0.974)	6.152*** (0.361)	5.238*** (0.485)	4.567*** (0.259)	8.125*** (1.311)	7.028*** (0.438)	3.400*** (0.367)	2.647*** (0.217)

Continued.

contemporaneously cross-sectionally correlated, and autocorrelated of type AR(1) (Table 7).

In the FGLS model, the following independent variables are examined: (i) Internet Retail Sales, (ii) GVC-weighted Income, (iii) LPI Score, (iv) Trade Openness, and (v) FDI. Since trade openness and FDI are highly correlated, they are estimated in two separate models. The FGLS estimator is known to be more efficient than the OLS in the presence of heteroscedasticity, as well as cross-sectional and serial correlations. All panel OLS and FGLS models yield empirical evidence on the positive and statistically significant impact of Internet Retail Sales and Mobile Internet Retail Sales on GVC exports (Models 1, 2, 5, and 6 of Table 4; and Models 1–4 of Table 5). These results bolster the importance of e-commerce in creating more opportunities for GVC exports. The coefficients of Internet Retail Sales (0.195–0.340) are relatively higher than those of Mobile Internet Retail Sales (0.114–0.131).

The coefficients for GVC-weighted Income are negative in both OLS and FGLS, but they are statistically significant only in the latter when controlled for heteroscedasticity and serial correlation (Models 1, 2, 5, and 6 of Table 4; and Models 1–4 of Table 5). When an exporting economy's income relative to an importing economy's increases, its GVC exports decrease and vice versa. This makes sense as the larger the importing economy's income relative to exporting economy's, the greater their import demand, leading to more exports from the exporter, given that import demand is a function of income. The same can be observed with an LPI Score where it shows a positive sign yet is only statistically significant in the FGLS estimations. The large magnitude of coefficients of the LPI Score (from 0.631 to 1.684) provides empirical evidence that logistics is the backbone of GVC exports.

When the Internet Retail Sales variable is used as a measure of e-commerce revenues, trade openness exhibits a positive and statistically significant impact on GVC exports for both panel OLS and FGLS estimations, increasing the GVC exports between 0.21% and 0.78% (Models 1 and 2 of Table 4). This provides empirical support to the importance of e-commerce and trade openness in stimulating GVC exports. However, when equation (1) is controlled for Mobile Internet Retail Sales as a measure of e-commerce revenues, the impact of trade openness on GVC exports is diminished and does not yield a statistically significant result. Neither OLS nor FGLS estimations involving Internet Retail Sales and Mobile Internet Retail Sales provide empirical evidence that FDI affects GVC exports.

Table 5. Regression Results of Panel Ordinary Least Squares and Feasible Generalized Least Squares

Dependent Variable: $\log(\text{GVC Exports})_{it}$				
	Model 1	Model 2	Model 3	Model 4
	Panel OLS	FGLS	Panel OLS	FGLS
$\log(\text{Mobile Internet Retail Sales})_{it}$	0.121*** (0.0391)	0.131*** (0.019)	0.115*** (0.0411)	0.114*** (0.017)
$\log(\text{GVC-weighted Income})_{it}$	-0.234 (0.300)	-0.244* (0.137)	-0.452 (0.277)	-0.243** (0.120)
$\log(\text{LPI Score})_{it}$	0.327 (0.233)	1.684*** (0.453)	0.839 (0.770)	1.669*** (0.402)
$\log(\text{Trade Openness})_{it}$	0.706 (0.726)	-0.103 (0.081)		
$\log \text{FDI} (\% \text{ of GDP})_{it}$			-0.130 (0.193)	-0.289*** (0.055)
Constant	9.849*** (1.134)	8.498*** (0.489)	10.22*** (1.485)	9.739*** (0.469)
Observations	117	117	117	117
Number of economies	13	13	13	13
Overall R^2	0.506		0.713	
Within R^2	0.397		0.336	
Between R^2	0.516		0.746	
F -statistic	84.296***		93.782***	
Correlation		Panel-specific AR(1)		Panel-specific AR(1)
Wald $\chi^2(4)$		122.52***		145.40***

FDI = foreign direct investment, FGLS = feasible generalized least squares, GDP = gross domestic product, GVC = global value chain, LPI = Logistics Performance Index, OLS = ordinary least squares.

Notes: FGLS model includes homoscedastic errors. Correlation: panel-specific AR(1) (PSAR1). Years are from 2011 to 2019. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Panel OLS estimations include year fixed effects. F -statistic is for the Wooldridge test of autocorrelation (H_0 : No first-order autocorrelation).

Source: Authors' calculations.

D. Two-Stage Least Squares Estimation

Generating unbiased estimates of the parameters in a panel data model and the OLS is grounded on two key assumptions: (i) the error term is uncorrelated with the independent variables; and (ii) there is homoscedasticity in the cross-section. The assumption that the error term is independent of the regressors (orthogonality condition) retains a potential problem—when the regressors are estimated with error, the orthogonality condition does not hold. The direction of the bias of the coefficients

is determined by the correlation among the variables, including the correlation among the measurement errors. Both sources of potential bias can be reduced by using instrumental variables and a 2SLS estimation technique. Employing this method allows us to further understand the implications of our data beyond the base model [equation (1)] by examining the underpinnings of e-commerce revenues as a key driver of GVC exports. Of particular concern is the potential for omitted variable bias, which could cause the error term to be correlated with some of the independent variables, given there could be various factors that affect GVC exports beyond the scope of the model used in this study.

Further investigation and analysis are undertaken to explore the potential problem of violating the assumption of noncorrelation of the error term with the independent variables in a panel data model. To examine the potential bias, it is imperative to investigate whether there is endogeneity with respect to the specified endogenous regressor (i.e., Internet Retail Sales) using equation (1). If the explanatory variables are not endogenous, the instrumental variable (IV) method is not relevant because the OLS method will produce more consistent and efficient parameters than the IV method.

The last rows of Tables 7 and 9 present the tests of endogeneity for Models 3 and 4 and Models 7 and 8 of Table 4, respectively, which show that there is evidence of endogeneity in the GVC exports equation. Across all models, the residual for the regression results of GVC exports is significantly different from zero based on the small *p*-value.

1. Instruments

We first introduce the instruments and relevant test statistics to evaluate their validity. To address the endogeneity of Internet Retail Sales_{*it*} representing B2C_{*it*}, it is instrumented by ICT and financial payment variables in the first stage:

$$\begin{aligned} \ln \text{Internet Retail Sales}_{it} = & \lambda_0 + \lambda_1 \ln \text{Debit Card Penetration}_{it} + \lambda_2 \ln \text{GWI}_{it} \\ & + \lambda_3 \ln \text{LPI Score}_{it} + \lambda_4 \ln \text{International Openness}_{it} \\ & + \lambda_5 \ln \text{International Internet Bandwidth}_{it-1} \\ & + \lambda_6 \ln \text{Technology Adoption}_{it} + \text{year}_t + \mu_{it}, \end{aligned} \quad (3)$$

where $\text{International Openness}_{it} = \text{Trade Openness}_{it}$, FDI_{it} ; and $\text{Technology Adoption}_{it} = \text{Internet Penetration}_{it}$, $\text{Server Penetration}_{it-1}$.

The excluded instruments in the second-stage regression are Debit Card Penetration_{*it*}, International Internet Bandwidth_{*it*}, and Technology Adoption_{*it*} measures. These technology and financial infrastructure variables, while having a direct impact

on B2C e-commerce, may not influence GVC exports directly. Since Internet Penetration and Server Penetration are highly correlated, two separate models are estimated to capture their respective impacts on Internet Retail Sales. While higher bandwidth and more secure servers can stimulate Internet Retail Sales, the growing popularity of e-commerce can also drive higher ICT infrastructure investments in internet bandwidth and the proliferation of supply-side technology adoption measures such as more firms adopting secure servers. The potential endogeneity of International Internet Bandwidth and Server Penetration through simultaneity problems in the first stage is further reduced by utilizing their lagged values, which are predetermined variables that cannot be influenced by their current values.

These variables must satisfy the following properties to be valid instruments: (i) correlated with the endogenous regressor (i.e., Internet Retail Sales); (ii) strongly correlated, rather than weakly correlated, with Internet Retail Sales; and (iii) uncorrelated with the error term or the exogeneity condition. The first two properties are necessary to establish the relevance of the instruments or that the excluded instruments are sufficiently correlated with the endogenous variable. The second property is a strengthening of the first to ensure good finite sample performance of the IV estimator.

The first property requires testing for underidentification, while the second tests for weak identification. We use the Kleibergen–Paap rk Lagrange multiplier to determine underidentification because it is robust to the heteroscedasticity of the error terms. Both tests are presented in the postestimation test results (Tables 6 and 8). The test rejects the null hypothesis of underidentification in all results at the 1% level of significance (first row for Models 3 and 4 of Table 7 and for Models 7 and 8 of Table 9). This suggests that the excluded instruments are correlated with the endogenous regressors (i.e., Internet Retail Sales) and, therefore, are relevant.

Stock, Wright, and Yogo (2002) proposed several informal procedures for detecting weak instruments including the first-stage R^2 and the first-stage F -statistic on the excluded instruments. The former measures the extent to which the excluded instruments explain the variation in the endogenous variable (i.e., Internet Retail Sales); the latter measures whether the coefficients of the excluded instruments are significantly different from zero. Tables 7 and 9 (second rows) show that the F -values in all models are well above the rule-of-thumb critical value of 10, following Staiger and Stock (1997). Meanwhile, the first-stage R^2 values in all models are relatively high. They explain from 57% to 69% of the variation in Internet Retail Sales, which is the endogenous variable (third rows of Tables 7 and 9). Both test statistics support the identification strategy and neither gives evidence against the instruments.

Table 6. Estimation Results: First Stage for Models 3 and 4 of Table 4

Dependent Variable: $\log(\text{Internet Retail Sales})_{it}$		
	Model 3	Model 4
$\log(\text{Debit Card Penetration})_{it}$	0.076 (0.145)	0.257** (0.105)
$\log(\text{International Internet Bandwidth})_{it-1}$	0.908*** (0.123)	0.791*** (0.111)
$\log(\text{GVC-weighted Income})_{it}$	0.682** (0.285)	0.453 (0.345)
$\log(\text{Trade Openness})_{it}$	-1.657*** (0.125)	-1.577*** (0.142)
$\log(\text{LPI Score})_{it}$	6.805*** (0.933)	8.443*** (1.29)
$\log(\text{Internet Penetration})_{it}$	0.300 (0.232)	
$\log(\text{Server Penetration})_{it-1}$		-0.116 (0.075)
Constant	-6.291*** (1.01)	-7.436*** (1.035)
Observations	129	113
R^2	0.912	0.919

GVC = global value chain, LPI = Logistics Performance Index.

Notes: Robust standard errors in parentheses. *** $p < 0.01$ and ** $p < 0.05$. Includes year fixed effects. Year coverage is from 2011 to 2019. The sample includes 14 Asian economies.

Source: Authors' calculations.

Stock and Yogo (2005) also proposed a more formal and rigorous process using the Cragg–Donald statistic, which is the generalization of the F -statistic. The null hypothesis tests whether or not the estimator is either weakly identified or biased and unacceptably large. Following the common practice in literature, we use the Stock–Yogo weak instrument test called the maximal IV estimator bias, which employs the ratio of the bias of the estimator to the bias of OLS (i.e., rows 4 and 5 of Tables 6 and 8 are evaluated using the Stock–Yogo maximal IV relative bias critical values).

The Cragg–Donald-based weak instruments test assumes homoscedastic errors. Hence, the heteroscedasticity-robust Kleibergen–Paap Wald rk F -statistic, which is valid under non-i.i.d. errors, is also shown. All results in rows 4 and 5 of Tables 7 and 9 show that both the Cragg–Donald and Kleibergen–Paap Wald rk F -statistics are above the 5% critical values. This suggests that the excluded instruments are correlated with the endogenous regressor (i.e., Internet Retail Sales). In effect, the null hypothesis that the instruments are weak is rejected.

Table 7. Postestimation Tests of Models 3 and 4 of Table 4

Null Hypothesis	Test Statistics	Model 3	Model 4
Instrument Relevance Tests			
Excluded instruments are irrelevant (underidentification)	Kleibergen–Paap rk LM statistic	30.42 (0)	31.19 (0)
All coefficients of excluded instruments are zero	Partial F -statistic in the first-stage regression	57.82++	56.97++
	Partial R^2 in the first-stage regression	0.554	0.582
Excluded instruments are weak (weak identification)	Cragg–Donald Wald statistic	46++	45.45++
	Kleibergen–Paap rk Wald F -statistic	57.82++	56.97++
Instrument Exogeneity (Overidentification) Test			
Instruments are not correlated with the error term and correctly excluded from the structural equation	Hansen's J -statistic	4.55 (0.103)	0.980 (0.613)
Test of Endogeneity			
Specified endogenous regressor (i.e., Internet Retail Sales) can actually be treated as exogenous	Difference-in-Sargan C -statistic	8.954 (0.003)	8.390 (0.004)

LM = Lagrange multiplier.

Notes: The p -values of LM, Hansen, and Sargan J -statistics are in parentheses. ++ denotes significance at the 5% level, according to the Stock–Yogo critical values.

Source: Authors' calculations.

Now that the relevance of the instruments has been established, their validity based on the third property was examined using Hansen's J -test of overidentifying restrictions. Hansen's J -statistic is robust to heteroscedasticity of error terms. In all results in Tables 7 and 9 (sixth rows), Hansen's J -statistics support the null hypothesis that the instruments are valid or uncorrelated with the error term and cannot be rejected. Hence, the excluded instruments are correctly excluded from the second-stage estimation [equation (1)] and the exogeneity or orthogonality condition is satisfied. Overall, the above results taken together provide convincing evidence in favor of the chosen instruments.

2. Results

All first-stage estimation results bolster the assertion that International Internet Bandwidth is the backbone of e-commerce (Models 3 and 4 of Table 6 and Models 7 and 8 of Table 8). This ICT infrastructure measure is statistically significant in all

Table 8. **Estimation Results: First Stage of Models 7 and 8 of Table 4**

Dependent Variable: $\log(\text{Internet Retail Sales})_{it}$		
	Model 7	Model 8
$\log(\text{Debit Card Penetration})_{it}$	0.271* (0.152)	0.352*** (0.118)
$\log(\text{International Internet Bandwidth})_{it-1}$	0.834*** (0.123)	0.794*** (0.104)
$\log(\text{GVC-weighted Income})_{it}$	0.448* (0.251)	0.174 (0.300)
$\log(\text{FDI (\% of GDP)})_{it}$	-1.073*** (0.063)	-1.07*** (0.071)
$\log(\text{LPI Score})_{it}$	4.228*** (0.842)	5.135*** (1.120)
$\log(\text{Internet Penetration})_{it}$	0.271* (0.152)	
$\log(\text{Server Penetration})_{it-1}$		0.352*** (0.118)
Constant	0.462 (1)	-0.519 (1.156)
Observations	129	113
R^2	0.928	0.933

FDI = foreign direct investment, GDP = gross domestic product, GVC = global value chain, LPI = Logistics Performance Index.

Notes: Robust standard errors in parentheses. *** $p < 0.01$ and * $p < 0.1$. Includes year fixed effects. Year coverage is from 2011 to 2019. The sample includes 14 Asian economies.

Source: Authors' calculations.

first-stage results and shows that Internet Retail Sales increase between 0.79% and 0.90%. These results are similar to the findings of Kang, Wang, and Ramizo (2021) on the impact of International Internet Bandwidth on B2C online commerce when the models are not controlled for time-invariant country characteristics. The regression results also provide empirical support on the crucial role of logistics performance in achieving higher e-commerce sales. Internet Retail Sales are highly responsive to changes in the LPI Score; a 1% improvement in logistics performance generates a 4.2–8.4% increase in e-commerce revenues.

Debit Card Penetration is positive and statistically significant across all models, except when Internet Penetration is used as a technology adoption measure, boosting e-commerce revenues by 25.7–35.2%. This result supports the findings of the United Nations Conference on Trade and Development (2017) on the significance of bank

Table 9. Postestimation Tests of Models 7 and 8 of Table 4

Null Hypothesis	Test Statistics	Model 7	Model 8
Instrument Relevance Test			
Excluded instruments are irrelevant (underidentification)	Kleibergen–Paap rk LM statistic	33.46 (0)	33.40 (0)
All coefficients of excluded instruments are zero	Partial F -statistic in the first-stage regression	64.91++	68.90++
	Partial R^2 in the first-stage regression	0.628	0.663
Excluded instruments are weak (weak identification)	Cragg–Donald Wald statistic	62.38++	64.18++
	Kleibergen–Paap rk Wald F -statistic	64.91++	68.90++
Instrument Exogeneity (Overidentification) Test			
Instruments are not correlated with the error term and correctly excluded from the structural equation	Hansen's J -statistic	1.890 (0.389)	0.747 (0.688)
Test of Endogeneity			
Specified endogenous regressors (i.e., Internet Retail Sales) can actually be treated as exogenous	Difference-in-Sargan C -statistic	4.499 (0.0339)	0.436 (0.509)

LM = Lagrange multiplier.

Notes: The p -values of LM, Hansen, and Sargan J -statistics are in parentheses. ++ denotes significance at the 5% level, according to the Stock–Yogo critical values.

Source: Authors' calculations.

accounts compared to Credit Card Penetration in B2C online sales payment readiness. A debit card usually has a corresponding bank account, which is not normally the case with credit cards. The responsiveness of B2C online sales generates the same result when using a different set of control variables (i.e., factors affecting consumer spending and various technology adoption measures such as internet access) and employing other estimation techniques (i.e., fixed-effect and random-effect models). The size and significance of the coefficients of Debit Card Penetration remain influential for B2C online commerce, suggesting that the results are not sensitive to variations in control variables or estimation methods.

The expected positive impact of technology adoption measures (i.e., Internet Penetration and Server Penetration) on e-commerce revenues finds empirical support when the model is controlled for FDI as a share of GDP. A 1% expansion of Internet Penetration, which represents the potential market size or customer base, boosts Internet Retail Sales by 0.27% (Model 7 of Table 8). Meanwhile, greater supply-side

technology adoption, through the proliferation of secure servers, enhances Internet Retail Sales by 0.35% for every 1% increase in the Server Penetration rate (Model 8 of Table 8).

The negative impact of Trade Openness and FDI seems puzzling but could be due to the fact that the majority of B2C e-commerce is still dominated by domestic commerce in many economies. The second-stage regression results, however, show the positive impact of these variables on GVC exports as expected. The GVC-weighted Income of exporters has a positive and statistically significant impact on Internet Retail Sales (Model 3 of Table 6, Model 7 of Table 8), with coefficients ranging from 0.45% to 0.68% when Internet Penetration is used as a technology adoption measure (Model 3 of Table 6, Model 7 of Table 8). This might also have been affected by the larger share of domestic commerce than cross-border commerce in B2C e-commerce statistics, which can be bolstered by the higher income of the source economy (i.e., the exporting economy in this case).

Examining the second stage of the 2SLS models shows the positive and highly statistically significant impact of Internet Retail Sales on GVC exports, which is robust across all estimation specifications and instrument variables used. The magnitude of coefficients of Internet Retail Sales is the highest when the instruments include Internet Penetration representing the potential e-commerce customer base. The coefficients are also stable across all model specifications with values ranging from 0.54% to 0.59% (Models 3, 4, 7, and 8 of Table 4). These results lend empirical support to the importance of e-commerce in generating more opportunities for GVC exports. All international openness indicators (i.e., Trade Openness and FDI) are positive and statistically significant and robust to variations in the excluded instrument variables. The parameters are also stable across specifications with a 1% increase in Trade Openness enhancing the GVC exports by 0.46–0.49% (Models 3 and 4 of Table 4), while a 1% increase in FDI expands the GVC exports by 0.30–0.32% (Models 7 and 8 of Table 4). These results are consistent with existing studies that point to the positive impact of international trade openness on GVC exports. Lastly, 2SLS estimation generates empirical evidence of the crucial role that logistics play in advancing GVC exports when the model specification uses FDI as a measure of international openness. A 1% improvement in the LPI Score drives up the GVC exports by 0.84%.

Further, while the PRC appears to be an outlier with its enormous e-commerce market size, which might affect the magnitude of the coefficients and even the direction of the signs, the results remain qualitatively the same across all estimation techniques and models even when the PRC is excluded from the sample.

IV. Conclusion

B2C online commerce, supported by rapid ICT innovation, is a powerful phenomenon that is reshaping the global economy. It has the capacity to link producers to consumers in novel ways through digital platforms that create online commercial spaces with domestic and international reach. This virtual marketplace enables firms to overcome the traditional initial fixed costs of reaching consumers (i.e., setting up physical stores) and create visibility for their products (i.e., marketing and advertisement initiatives). It also empowers consumers by giving them a massive list of products to choose from and more actively engaging them in product development and service delivery improvement through various feedback and reputation mechanisms.

In fact, these new economic arrangements raise questions about the impact of B2C online commerce on GVCs. This paper's empirical analysis finds robust evidence that various segments of B2C online commerce facilitate GVC exports, suggesting that the size of B2C online commerce in a given economy contributes to the growth of its GVC exports. GVC exports rely on intermediate or final products with final destinations being either in the product's origin economy or abroad. Hence, the results lend support to the discussion that B2C online commerce provides a convenient platform for firms to sell their products and for consumers to engage in feedback cycles, thereby promoting further fragmentation of cross-border production stages along and within the stream of research and development, design, production, marketing, and logistics before selling the products both domestically and abroad. Our IVs of technological factors and payment mechanism play a key role. The robust and positive impact of secure internet servers and internet bandwidth on B2C online commerce, as well as the positive influence of B2C online commerce on GVC exports, provides empirical evidence of the interrelationship of technology adoption, B2C online commerce, and GVCs.

The findings can guide policymakers in Asia given the yawning digital divide in parts of the region and digital solutions' untapped potential in B2C online commerce. The problem of a digital divide—whether it is between urban and rural areas, income classes, or genders—could leave many people, particularly the disadvantaged, behind if unaddressed by appropriate policy measures. High-quality access to the internet, particularly international internet bandwidth, is vital to stimulating cross-border trade and domestic commerce. Our policy recommendations include greater investment in ICT infrastructure, both public and private, and the creation of an enabling environment that promotes competition in the telecommunications sector. The direct

effect of secure servers and financial readiness on B2C online commerce, and its indirect impact on GVC exports, emphasizes the importance of laws and regulations that enable both businesses and consumers to benefit from digital payment systems and data protection.

The emerging digitally powered, knowledge-intensive GVCs are likely to dominate the future (Inomata and Taglioni 2019). As digital infrastructure advances, GVCs will likely also evolve in terms of their governance structure, expansion, and value creation and capture, with the impact of new digital technologies on GVCs reinforced by digital platforms and ecosystems.

Integrating into and benefiting from GVCs can be further promoted with the growth of B2C online commerce. For this, developing economies need access to ICT infrastructure, a skilled workforce, and local governance that nurtures supporting institutions and a market environment conducive for digital transactions. Strong government support is thus needed to strengthen investments in both hard and soft infrastructures and human capital, and to improve the quality of institutions.

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