Empirical Study of the Impact of Cross-Border Data Flow Restrictions on Digital Service Exports

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Abstract. China is an important digital industry and data trading power in the world, but compared with the rapid development of data trade, the formulation of China's data trade export rules is far behind. Based on the econometrics model of ITIF, based on the cross-border digital service trade data of OECD member countries, the paper uses the PMR and data restriction index DRI to build the OECD to evaluate the cross-border data flow of the OECD countries; uses the corrected data intensity DIM to evaluate the impact of different industries by cross-border flow of data restrictions; and uses the DRL to evaluate the impact of the specific country-industry level restriction policies. On this basis, the linear regression of the impact of national digital export (trade volume GOV, productivity TFP, price PVA) on the correlation degree of DRL is constructed, and the specific impact of cross-border digital flow policy restrictions on national digital export is studied.

Keywords: Cross-border data flow · digital services · cross-border data flow restrictions

1 Introduction

In recent years, with the development of technologies such as the Internet, artificial intelligence and big data, digital trade has gradually become an important part of international trade. The network enables the high-speed flow of various resources and information within and outside a country, greatly improving the efficiency of using data. As a major data producing and using country, China occupies a more significant share in the world digital economy and data trade industry. According to the Ministry of Commerce, China's digital economy industry reached $3.5 trillion in 2020, and the foreign digital trade industry reached a trade size of $14 trillion. It is expected that by 2025, China will become the world's largest digital economy industry and will account for more than 25% of the world's total digital economy industry [1]. The flow of information can, to a certain extent, reduce the transaction costs of international trade and improve the convenience of trade, thus reducing the cost of individuals, small and medium-sized enterprises and developing countries to participate in related trade and industries; moreover, the increased scale of data flow can make market information more instantaneous

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and open, enhance the mutual communication and understanding of market subjects, and promote the goods and service providers with the help of data. This will enrich the variety and specific content of goods and services, enhance user stickiness, and at the same time force the supply chain to improve its production and deployment capabilities. However, compared with the rapid development of digital trade, the development of China's digital trade export rules is lagging far behind.

According to the definition of Business Software Alliance, cross-border data flow refers to the transmission and distribution of information data across countries and borders. The Organization for Economic Co-operation and Development (OECD) believes that cross-border data flows should meet two conditions: first, the data should be recognized by computers or electronic devices, and second, the data should cross the border of a country. Based on these two conditions, the International Center for Transnational Data Exchange (ICDE) believes that another condition should be added: a series of processing operations such as preservation, transmission and parsing of data should be carried out [2]. In this paper, we believe that cross-border data flow is the transmission and operation of data across physical national boundaries, and the data can be accessed and utilized by individuals or organizations in third countries although they do not actually reach outside the country [3].

2 Analysis of the Impact of Cross-Border Data Flow Restrictions on Digital Service Exports

2.1 New Protection Barriers to the Formation of Digital Trade

Data localization constitutes a new type of protection barrier for contemporary digital trade. Data localization requires localization of data that are generally considered important, sensitive or highly confidential by the country where the data are located, and are closely related to national security; on the other hand, the in-depth knowledge and accelerated construction of cyber sovereignty in some countries, as well as the censorship system for data, will make data localization appear frequently. Therefore, data localization can also be considered as a relatively new manifestation of digital trade protectionism. For example, a 2016 French ministerial circular announced that data generated by the public administration cannot be stored in cloud servers that are not "sovereign" (meaning foreign), but only in archives within France. In 2021, two French tech giants, Capgemini and Orange, announced plans to create a trusted cloud called "Bleu", which would meet the French public authorities' requirements for cyber sovereignty over data use while creating a sovereign cloud within the EU. While this measure solves the problem of data localization between France and the rest of the EU, it undoubtedly creates new barriers to data protection between EU and non-EU countries. Data localization within the EU, on the other hand, is even more pronounced, with personal data being able to flow freely between European Economic Area (EEA) countries and selected countries deemed secure enough in terms of data protection under the General Data Protection Regulation in 2018. In order to transfer data to any other country, there must be a binding contractual agreement, the same subject of the data, or the data transfer must be necessary to enforce the data subject's contract. In 2019, France and Germany led a project within the EU called "GATA-X", which plans to build a European cloud system to fight for "digital sovereignty" and to break the heavy dependence on U.S. cloud companies (e.g., Microsoft, Azure cloud services, Amazon Web Services) and The European cloud system is defined as a "trusted cloud" for storing public data of EU member states. It defines digital sovereignty as the right of the EU to be autonomous in the digital world and not to be subject to external interference from other countries, unions or institutions within the digital world. The construction of this project is essentially the construction of the EU's protection barriers to U.S. data cloud services [4].

2.2 Inhibiting Innovation in the Digital Economy

Data localization hinders the further development of the global digital economy, undermines the basic rules of digital economy development, and inhibits potential innovation within the digital economy industry. The Internet focuses on the openness, collaboration and sharing of information, data and knowledge outcomes. Since the large-scale commercialization of the Internet, a large number of enterprises have relied on the Internet infrastructure to carry out related businesses, giving rise to an O2O-like business model. This paper argues that enterprises need to rely on the Internet and use data to create business value, and only the free flow of data across borders can maximize the commercial value of their data. Therefore, data localization makes data-intensive services contribute less to productivity and innovation outcomes. OECD states that digitization brings a higher degree of trade opening, selling related products to more offshore markets; a 10% increase in bilateral digital trade connectivity would increase the volume of services trade by more than 3.1% [5].

2.3 Reducing the Potential for Shared Governance

Data localization reduces the potential and possibility of shared governance to some extent. Due to the numerous differences in policies governing the oversight of data custody between countries in terms of deterring domestic espionage, maintaining national financial stability and security, conducting law enforcement investigations, and conducting homeland geodata mapping updates. This undoubtedly brings high economic and trade costs and restrictive policies to the free flow of data across borders, and discourages countries from integrating relevant resources to share, exchange and learn effective methods and policies of data governance with other countries. The added value of data generated in different countries and within their borders varies, which has led to many differences in the policies adopted by countries for cross-border data flows. China and the U.S. are increasingly intensifying their trade frictions and games, and the cross-border data flow game is a very important part of the national interests of both countries. In the value chain of the digital economy, the U.S. is located in the middle and high end. Compared to China, it has a comparative advantage in digital services trade [6]. The U.S. is the dominant country in digital content, digital rule-making, etc., and a major global exporter. For example, iTunes is an official music player developed and launched by Apple in the U.S. with the intention of integrating digital music singles and albums, music videos, etc. into this platform. It even introduced an exclusive audio file encoding format called ALAC (Apple Lossless Audio Codec), which became one of the key file formats in the global audio industry. Apple purchased the rights to sell millions of songs from several major record companies (EMI, Warner Records, Universal Records, Synergy Boardman, etc.) in 2003, and users were able to listen to the music freely on their own devices by purchasing digital versions online using iTunes, while Apple paid a proportional share of the revenue from the sales of single songs to the record companies. Against the background of the gradual coverage of smartphones and high-speed mobile networks around the world, people in the European and American music markets are gradually changing their past habits of buying physical tapes and CDs to listen to music and using Apple's iTunes instead, which has gradually strengthened Apple's position in the digital music field and gained further recognition in the market, making it the dominant player in digital music content distribution and digital music platform operation. In addition, the U.S. government enacted the "Clarifying Lawful Use of Offshore Data Act" in 2019, and this act gives the government the right to access data located in the territory of other countries across borders. Excessive interference with cross-border data and transnational enforcement effectively brings the effect of domestic laws to the country where the data is located, which clearly poses a threat to the integrity of data sovereignty and poses a serious challenge to the governance of multilateral data flow sharing on a global scale [7–10]. Compared to the U.S., China occupies a much smaller share of the value chain of the digital economy, located at the lower and middle ends, with a comparative advantage in the trade of goods based on online e-commerce platforms, and a greater focus on the mastery of digital sovereignty in the digital economy, for example, the need for payment mechanisms, privacy and reliability of cross-border goods and digital trade.

3 Indicator and Model Selection

In this paper, we have utilized the indicators and models that put forth by Information Technology and Innovation Foundation (ITIF) [11].

3.1 Indicator Selection

Product Market Regulation (PMR)

The Product Market Regulation (PMR) is an indicator to monitor anti-competitive behavior (common behaviors such as dumping, price fixing, price fixing, etc.) in the product market of each member country. The PMR index covers barriers to entrepreneurship, trade and investment, etc. The economy-wide PMR indicator covers the following non-manufacturing sectors: (1) seven major infrastructure and logistics sectors (electricity, gas, telecommunications, postal services, air, rail, and road transport); (2) professional services (information technology, legal, accounting, engineering, and architectural services); and (3) retail trade. Indicator is updated every five years, with the latest data updated in 2018. Therefore, the data used in this paper covers the period from 1975 to 2018.

The OECD Regulation Impact (REGIMPACT) indicator is calculated using the degree of regulation of Non-Manufacturing Industries (REGNMI) and the total input-output coefficient w for the above non-manufacturing sectors, where $w_{j,k}$ denotes the total intermediate input of non-manufacturing sector j to sector k. The REGIMPACT indicator shows the relevance of the regulatory framework of the industries covered by the PMR indicator to other industries. The formula is as follows:

$$REGIMPACT_{c,k} = \sum_{j=1}^{n} REGNMI_j * w_{c,j,k} \quad (1)$$

Due to the important role of these non-manufacturing sectors as suppliers of intermediate inputs in OECD member countries, the knock-on effects are more pronounced in other economic sectors. This paper is based on the maximum-minimum standardization of the REGIMPACT indicator for better comparison across countries and sectors. Where X_{min} denotes the minimum value of standardization $\widehat{REGIMPACT}$ across member countries and industries. X_{max} denotes the maximum value. This makes $\widehat{REGIMPACT}$ of each industry in each member country all fall within the interval [0, 1].

$$\widehat{REGIMPACT} = \frac{REGIMPACT_{c,k} - X_{min}}{X_{max} - X_{min}} \quad (2)$$

Data Restriction Index (DRI)

The Data Restrictiveness Index (DRI) refers to how much the data policies and regulations of a country's restricts the flow of data across borders. ITIF constructed this index with sub-indicators from the OECD's PMR indicators database. By calculating the average of selected PMR sub-indicators, DRI is calculated for 46 countries within the OECD for which PMR data are available. As the PMR data are calculated every five years, the DRI data are also calculated every five years, and the range of DRI is [0,6], where 6 indicates the maximum restriction on data flow by the relevant national policies. If a country implements laws and regulations that restrict data flow (e.g., localization of data, etc.), the DRI of a country will increase as the number of related policies increases and their implementation becomes stronger. Obviously, a country's data restriction policies are highly negatively correlated with the overall data intensity of the country. The stricter the data restriction policy, the lower the overall data intensity.

In the 2018 assessment, the DRI indicators were further refined from "administrative barriers to startups" and "administrative and regulatory opacity", as they were before 2018, to five secondary indicators: "assessment of the impact on competition", "interaction with interest groups", "complexity of the regulatory process", and "barriers to services", "assessment", "interaction with interest groups", "complexity of regulatory procedures", "barriers in the service sector", "Barriers in the infrastructure logistics sector". These five secondary indicators are included in the two primary indicators "Simplification and assessment of regulations" and "Barriers in the services and infrastructure logistics sectors", which largely overlap with the two previous indicators for 2018. To ensure that the 2018 DRI indicators used are consistent with the DRI indicators prior to the rule change, the correlation between the 2018 DRI and PMR indicators is calculated and compared with the correlation between the DRI and PMR prior to 2018.

The formula for the DRI_{old} calculation in 2013 is as follows:

$$DRI_{old} = \frac{X_1 + X_2}{2} \quad (3)$$

where X_1 represents administrative barriers for startups, and X_2 represents administrative and regulatory opacity.

The 2018 DRI_{new} is calculated as follows:

$$DRI_{new} = \frac{Y_1 + Y_2 + Y_3 + Y_4 + Y_5}{5} \tag{4}$$

where $Y_1 Y_2$, Y_3, Y_4, Y_5 represent "assessment of competitive impact", "interaction with interest groups", "complexity of the regulatory process", "barriers in the services sector", and "barriers in the infrastructure logistics sector", respectively. Thus DRI_{new} gives a general picture of the data intensity of a country in relation to other countries.

This paper measures the DRI sub-indicator and DRI data for each OECD member country (2008, 2013) as shown in Table 1.

Data-Intensity Modifier (DIM)

Based on the DRI, in order to better verify the impact of data regulation policies on data intensity in different industries, this paper proposes the Data-Intensity Modifier (DIM). The ratio of Non-capitalized Software Expenditures (NSE) to the number of workers in an industry, which represents the amount of data demanded and relied on in an industry, is used to represent the expenditures per worker for data-related services in each industry. This ratio forms a natural logarithmic relationship with DIM. The formula is as follows:

$$DIM_i = ln \frac{NSE_i}{L_i} \tag{5}$$

where NSE_i indicates industry non-capitalized software expenditures in millions of dollars; L_i denotes the industry the number of people in the workforce.

Data Restrictiveness Linkage (DRL)

Data Restrictiveness Linkage (DRL) refers to the estimation of the impact of a country's data restriction policy on the data intensity of a particular industry in a given year based on the degree of data restriction in each country and the data intensity of each industry in a country. The product of DRI of a country and DIM of a specific industry is used to represent the DRL of a country's industry. In this paper, we use this model to construct regressions for trade output, prices and productivity respectively to calculate the degree of impact of data restriction policies on digital exports of a specific industry in an OECD member country. The formula is as follows:

$$DRL_{c,i} = DRI_c * DIM_i \tag{6}$$

The EU-KLEMS database is an important database that contains the economic growth and productivity of European countries for the last 20 years (1997–2018). In this paper, indicators are selected from the EU-KLEMS database for the regression of DRL. Gross Output Volume (GOV) represents the volume of trade output, Total Factor Productivity (TFP) represents productivity, and Price Index based on Added Value (PVA) represents prices. The formulas are respectively as follows:

Regression of trade volumes:

$$\ln(GOV_{cit}) = \phi + \Theta * DRL_{cit-1} + \delta_{ct} + \gamma_{it} + \varepsilon_{cit} \tag{7}$$

Regression of productivity:

$$\ln(TFP_{cit}) = \phi + \Theta * DRL_{cit-1} + \delta_{ct} + \gamma_{it} + \varepsilon_{cit} \tag{8}$$

Table 1. PMR and DRI and correlation coefficients by OECD member countries (2008, 2013, 2018)

	2008		2013		2018	
Country	PMR2008	DRI_{old} (2008)	PMR2013	DRI_{old} (2013)	PMR2018	DRI_{new} (2018)
Australia	1.44	1.54	1.27	1.60	1.16	1.26
Austria	1.37	1.74	1.19	1.52	1.44	2.10
Belgium	1.52	2.51	1.39	2.00	1.69	2.17
Canada	1.53	1.30	1.42	1.30	1.76	1.47
Chile	1.75	3.06	1.51	2.44	1.41	1.97
Colombia	-	-	-	-	2.04	2.84
Costa Rica	-	-	-	-	2.32	2.76
Czech Republic	1.51	2.37	1.41	2.30	1.30	1.41
Denmark	1.34	1.71	1.21	1.29	1.02	1.53
Estonia	1.37	2.17	1.29	1.94	1.29	1.37
Finland	1.34	1.70	1.29	1.69	1.37	1.53
France	1.52	1.93	1.47	1.87	1.57	1.31
Germany	1.40	2.13	1.28	1.79	1.08	1.23
Greece	2.21	3.12	1.74	2.22	1.56	2.42
Hungary	1.54	2.55	1.33	1.79	1.32	1.94
Iceland	1.48	2.42	1.50	2.30	1.44	2.02
Ireland	1.35	2.39	1.45	2.43	1.38	1.66
Israel	2.23	2.82	2.15	2.78	1.41	1.31
Italy	1.51	1.40	1.29	1.33	1.32	1.92
Japan	1.43	1.69	1.41	1.68	1.44	1.76
Korea	1.94	2.35	1.88	1.94	1.71	1.59
Latvia	-	-	-	-	1.28	1.84
Lithuania	-	-	-	-	1.19	1.15
Luxembourg	1.44	1.93	1.46	1.90	1.68	1.99
Mexico	2.05	2.23	1.91	1.92	1.61	1.53
Netherlands	0.96	1.31	0.92	1.16	1.10	1.29
New Zealand	1.23	1.12	1.26	1.11	1.24	1.52
Norway	1.54	1.88	1.46	1.71	1.15	0.98
Poland	2.04	3.20	1.65	1.97	1.45	1.25
Portugal	1.69	2.12	1.29	1.44	1.34	2.23
Slovakia	1.62	2.09	1.29	1.27	1.52	1.63
Slovenia	1.89	2.40	1.70	2.15	1.29	1.68
Spain	1.59	2.71	1.44	2.58	1.03	1.31
Sweden	1.61	2.18	1.52	2.11	1.11	1.09
Switzerland	1.55	1.59	1.50	1.54	1.53	1.48
Turkey	2.65	3.45	2.46	3.28	2.28	2.09

(*continued*)

Table 1. (*continued*)

	2008		2013		2018	
Country	PMR2008	DRI_{old} (2008)	PMR2013	DRI_{old} (2013)	PMR2018	DRI_{new} (2018)
United Kingdom	1.21	2.27	1.08	1.91	0.78	0.75
United States	1.59	1.32	1.59	1.27	1.71	1.73
Correlation coefficient	0.710		0.696		0.704	

Regression of price:

$$\ln(PVA_{cit}) = \phi + \Theta * DRL_{cit-1} + \delta_{ct} + \gamma_{it} + \varepsilon_{cit} \tag{9}$$

GOV_{cit}, TFP_{cit} and PVA_{cit} are references to country indicators for which the data intensity of the industry is affected in a given year. ϕ refers to the intercept term, and DRL_{cit-1} is the degree of data restriction linkage for a particular country industry in the previous data year. The first-order lag added here indicates the difference between year t and the previous year $t-1$. DRL for the data year constitutes a regression relationship, and realistically, it takes time for the economic impact of policy restrictions on cross-border data flows to manifest itself. δ_{ct} denotes exporting economy-year fixed effects, and γ_{it} denotes export economy-specific industry-years fixed effects, expressing country and industry changes in a given year that cannot be represented by the model, respectively. ε_{cit} is the random error term. The reason for using log-linear regressions is that the coefficients of log-linear regressions are able to change as a percentage when the independent variable changes by units, which more intuitively represents the extent of the impact of data restriction policies on the economy.

3.2 Parameter Estimation

In this paper, we chose to select data from 21 of the OECD member countries for measurement, and all parameter estimates are statistically significant above the 90% confidence level. As shown in Table 2, the estimated p-value of PVA reaches 95% confidence level, while TFP and GOV reaches 99% confidence level. They are highly significant. Therefore, the parameter estimates of DRI can reflect the percentage changes of GOV, TFP, and PVA resulting from a one-unit increase in DRI of a country.

In summary, data from a sample of 21 member countries in the EU-KLEMS database show that when a country's DRI increases by one unit, it will bring about an economic impact of 8.12% reduction in total trade output, 3.8% reduction in productivity of related industries, and 2.0% increase in prices of goods and services in related industries over a five-year period. This proves that the model makes economic sense. In this context, it is necessary for policymakers and decision makers to consider the overall macroeconomic impact of data restriction policies. Further restrictions on cross-border data flows could lead to numerous problems and trigger a chain reaction. A decrease in total trade output represents a decline in total trade, leaving a country with less foreign exchange earnings. A decline in productivity in one industry may be amplified in downstream industries,

Table 2. Regression Results

Dependent variable	Parameter estimation of DRL	p-value estimation	Standard deviation	δ_{ct}	γ_{it}
$\ln(GOV_{cit})$	-0.08124	0.000652***	0.0073	Control	Control
$\ln(TFP_{cit})$	-0.03796	0.000437***	0.0081	Control	Control
$\ln(PVA_{cit})$	0.01985	0.0021**	0.0012	Control	Control

Note: *** and ** indicate at 1% and 5% significance levels, respectively

putting downward pressure on GDP growth as shortages of raw materials bring about greater productivity declines and output shortfalls. Higher prices of related goods and services may lead to a decline in the standard and quality of living of the population. All of these may ultimately point to a country's sluggish economic growth or even an ongoing recession over a longer period of time.

From this paper, we conclude that: (1) The introduction of restrictive policies on cross-border data flows and tighter restrictions on data flows will reduce the volume of trade output. Generally speaking, a 1 unit increase in a country's DRI will make its total trade output decrease by 8.12% in 5 years. This indicates that all industries need to use or transmit a certain amount of data to facilitate foreign trade, and the percentage reduction must be higher in industries with high data intensity such as information technology and financial and insurance services. (2) Increased restrictions on the flow of data would reduce productivity by 3.8%. This indicates that data play a role as a factor of production in the production process of industries. Delayed availability or even absence of some data may lead to slow or even unsustainable progress of data-dependent production activities, reducing the productivity of industries. (3) Increased restrictions on data flows will cause prices of goods and services in related industries to increase by 2.0%. This is due to a reduction in the supply of software and services related to data analysis and data management, resulting in a decrease in the trade volume of related products and a consequent increase in the prices of data-dependent downstream goods and services.

3.3 Model Testing

Goodness-of-fit test.

In this paper, the goodness-of-fit of the three models is examined, and it can be seen from Table 3 that the goodness-of-fit of the three models is generally good.

Heteroskedasticity test.

Table 3. Goodness of fit of each model

Dependent variable	$\ln(GOV_{cit})$	$\ln(TFP_{cit})$	$\ln(PVA_{cit})$
R^2	0.9421	0.9064	0.8577

The data for 11 industries in 21 sample countries used in this paper are large sample time series data, and the heteroskedasticity that is considered to exist is the ARCH autoregressive conditional heteroskedasticity process, and the existence of heteroskedasticity in the time series is determined by testing whether this process holds.

Let the ARCH process be

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + v_t \tag{10}$$

where $\alpha_0 > 0, \alpha_1 > 0$. Find the residuals e_t for the original model and calculate the series of squared residuals e_t^2, e_{t-1}^2, which are used as pairs of σ_t^2 and σ_{t-1}^2 respectively. Next, we calculate the auxiliary regression, $\widehat{e}_t^2 = \widehat{\alpha}_0 + \widehat{\alpha}_1 e_{t-1}^2$. Then calculate the product of coefficient of determination of the auxiliary regression R^2 with $(n-1)$, $(n-1)R^2$. In holds of H_0, based on a large sample, $(n-1)R^2$ obeys a cardinal distribution with degree of freedom 1. Given the significance level α, check the distribution table of $\chi^2(1)$, we can get the critical value $\chi_\alpha^2(1)$. If $(n-1)R^2 > \chi_\alpha^2(1)$, then the original hypothesis is rejected, indicating that there is heteroskedasticity in the random error term in the model. From the calculation, we can see that in the actual model, $(n-1)R^2 < \chi_\alpha^2(1)$. So the original hypothesis is accepted and $\sigma_t^2 = \alpha_0 + v_t$. Therefore, there is no heteroskedasticity.

Autocorrelation test.

Due to the large sample size, the DW test is not applicable, and the Lagrange Multiplier test is used in this paper, which is applicable to the case of higher order serial correlation and the presence of lagged explanatory variables in the model.

For model

$$\ln(GOV_{cit}) = \phi + \Theta * DRL_{cit-1} + \delta_{ct} + \gamma_{it} + \varepsilon_{cit} \tag{7}$$

We detect presence of 1st order serial correlation in ε_{cit}:

$$\mu_t = \rho_1 \mu_{t-1} + v_t \tag{11}$$

The LM test can be used to test the following constrained regression equations:

$$e_t = \rho_1 e_{t-1} + v_t \tag{12}$$

It has been proved that with large samples

$$nR^2 \sim \chi^2(1) \tag{13}$$

where n is the sample size, and R^2 is the coefficient of determination of the auxiliary regression. Given α, check the critical value $\chi_\alpha^2(1)$ for comparison, and then make a judgment. From the calculation, we can see that $nR^2 < \chi_\alpha^2(1)$, there is no autocorrelation in the model.

4 Empirical Measurements for China

4.1 Overall Impact

In this paper, we obtain the PMR data of China in 2013 and 2018 from OECD's PMR database to calculate the impact of the degree of data flow restrictions on digital trade exports during the five years from 2013 to 2018. And the DRL data is calculated based on the previous indicators. As shown in Table 4.

Table 4. China DRL data

Year	Industry										
	Public Utilities	Wholesale Trade	Retail Trade	Logistics and warehousing	Information Technology Services	Financial Activities	Professionalism and business services	Educational Services	Health and Social Services	Leisure and hospitality	Other Services
2013	30.11	22.47	21.61	22.15	30.88	29.76	23.36	21.84	20.95	13.46	18.55
2018	32.83	24.95	24.24	23.54	33.78	32.42	25.40	24.57	23.33	18.09	21.06

Table 5. Changes in the extent of data restrictions in China and the impact on digital trade exports (2013–2018)

2013 DRI	2018 DRI	DRI Difference	Total Trade Volume Change GOV	Productivity changes TFP	Price Change PVA
3.88	4.13	0.25	-2.16%	-0.92%	0.58%

Then the percentage changes of GOV, TFP and PVA are calculated by substituting into Eqs. 7, 8 and 9, respectively. It is worth noting that our DRI indicators in 2013 and 2018 are higher than those of all OECD member countries, indicating that our country has a higher degree of stringency for cross-border data restrictions. We can see in the five-year period from 2013 to 2018, the DRI increased by 0.25, further increasing the degree of restrictions on cross-border data. Such restrictions resulted in a 2.16% decrease in total trade, a 0.92% decrease in productivity, and a 0.58% increase in the prices of downstream digital-related industries, goods and services trade, as indicated in Table 5.

4.2 Heterogeneity Analysis

Considering the hypothesis that all countries have the same level of technology as the benchmark country: the U.S., this paper considers that Chinese industries also have the same level of technology as the U.S. industries. Four industries: financial activities, information technology, education, and leisure and hospitality, are selected to conduct regression analysis on the impact of cross-border data flow policies on digital trade in different industries using data for three years, 2018, 2013, and 2008, respectively. The results are as follows:

As can be seen from Table 6, policies on cross-border data flows have a more significant restrictive effect on financial activities and information technology, causing digital

Table 6. Heterogeneity Analysis of Restrictive Policies on China's Digital Trade Exports (2013–2018)

Dependent variable	Industry ($i = 1, 2, 3, 4$)				δ_{ct}	γ_{it}
	Financial Activities	Information Technology	Education	Leisure and hospitality industry		
$\ln(GOV_{cit})$	-0.14578*** (0.00245)	-0.23781*** (0.00977)	-0.05350** (0.0221)	-0.04719** (0.0483)	Control	Control
$\ln(TFP_{cit})$	-0.07794** (0.0387)	-0.11352** (0.0219)	-0.02116** (0.0199)	-0.01855** (0.0517)	Control	Control
$\ln(PVA_{cit})$	0.02569*** (0.00108)	0.06933*** (0.00354)	0.01492*** (0.00240)	0.01097*** (0.00468)	Control	Control

Note: *** and ** indicate at 1% and 5% significance levels, respectively

Table 7. Comparison of DRI values between OECD member countries and China (2013, 2018)

Year	Maximum DRI value for OECD member countries	China DRI values
2013	3.28	3.88
2018	2.84	4.13

trade exports to fall by 14.58% and 23.78%, total factor productivity to fall by 7.79% and 11.35%, and export product prices to rise by 2.57% and 6.93%, respectively. In contrast, the education and leisure and hospitality sectors were relatively less affected by the policy, with digital trade exports declining by 5.35% and 4.72%, total factor productivity declining by 2.12% and 1.86%, and export product prices increasing by 1.49% and 1.1%, respectively.

4.3 DRI Analysis

This study concludes that China's DRI values are higher than those of all OECD member countries. The specific data are shown in Table 7.

This indicates that our country has adopted stricter restrictions on the cross-border flow of data compared to individual member states. Our Cybersecurity Law, Draft Personal Information Protection Law, and Data Security Law are the core of the data governance framework, and each includes a large number of data localization measures. However, even with these three main pieces of legislation, the actual operational situation is more complex than the legal provisions due to the large number of sectors and industries involved, and the specific regulations related to data localization and cross-border data transfer are still being introduced and improved. The combing of China's policies, laws and regulations on data cross-border restrictions reflects the reasons for the relatively higher data restriction index DRI and stricter restrictions on cross-border data flow. This paper argues that similar to countries such as Turkey and Greece, China also has restrictions on cross-border flow of important and sensitive data involving customer privacy and national security in the information technology and financial industries.

4.4 Conclusion

First, the restrictions on the free flow of cross-border data have a negative impact on the export of digital services. Various countries have implemented data localization policies in consideration of the importance of data sovereignty, data security, and national security. However, such policies have the consequence of restricting the free flow of cross-border digital services. In this paper's model, policy restrictions lead to a decrease in total trade, a decrease in productivity, and an increase in the prices of downstream digital-related industries, goods, and services.

Second, the trade effects presented by cross-border data free flow restrictions vary across industries. In financial services and information technology services, which are traditionally highly data-dependent and data-producing industries, cross-border digital free flow will be able to remove trade barriers to some extent and increase the possibility of cross-border remote online services for industry practitioners. At the same time, due to the design of individual privacy and national security of the data they use, their free flow may be restricted by national data localization policies, which will have a greater impact on their digital exports. On the other hand, the education and intellectual property industries are relatively less dependent on data, and the free flow of cross-border digital may bring problems such as illegal copying and piracy and difficulties in defending rights across borders, while relevant policy restrictions may also affect the education industry, but in general liberalization of the free flow of digital allows related products to be widely disseminated outside the country to bring more benefits than losses caused by piracy.

Third, the development of information technology will have a positive impact on the free flow of cross-border digital. With the development of information technology and the popularity of the Internet, the Internet has become an important vehicle for conducting digital trade services. The development of information technology (e.g. 5G technology) means the efficiency of cross-border digital flow is improved, while the level of Internet penetration is related to whether an industry or even a country can carry out cross-border digital flow more smoothly, thus driving the export of digital services. The popularity of the Internet also means the growth of the scale of Internet users, which makes the user group complex and the user needs diversified, and the cross-border digital mobility industry brought about will be more abundant. For example, users can edit documents in real time through online office platforms and collaborate and communicate with others across borders; international video platforms allow users to follow and consume entertainment content they are interested in through subscription-based content distribution, and even show their support by rewarding anchors who are abroad through cross-border payment platforms, thus satisfying users' needs for personalized digital services.

The sample data used in this model is based on the EU-KLEMS database for 21 OECD countries, but the model can be used for other countries outside the OECD. The reason is that DRI and DRL are not precise measures of the strength of data restriction policies, but rather represent the relative level of restriction in terms of numbers, and the values of the indicators for specific countries may have some deviation compared with the actual situation of data restriction. Although the policies vary from country to country, it is possible to reflect the degree of data flow restrictions through the PMR and other indicator values, and substitute them into the model to obtain the specific degree of economic impact.

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