Journal of Asian Economics 87 (2023) 101621

Contents lists available at ScienceDirect

Journal of Asian Economics

journal homepage: www.elsevier.com/locate/asieco

Higher education expansion and domestic value added in exports: Theory and evidence from China

Yan Du [a], Jie Yan [b], Fangzhou Cao [b], Yifei Li [c,*], Mao Zhou [b]

[a] School of Public Finance and Taxation, Southwestern University of Finance and Economics, 555 Liutai Avenue, Wenjiang District, Chengdu, Sichuan 611130, China
[b] School of International Business, Southwestern University of Finance and Economics, 555 Liutai Avenue,Wenjiang District, Chengdu, Sichuan 611130, China
[c] Journal of Management World, 4th Floor, Building 1, No. 2 Courtyard, Jintaili, Hongmiao, Chaoyangmen, Beijing 100026, China

ARTICLE INFO

JEL Classification:
F14
F16
I25
J24

Keywords:
Human capital
Higher education expansion
Domestic value-added rate

ABSTRACT

This paper analyzes the impact of China's higher education expansion on domestic value added in exports. To be specific, we firstly construct a nested CES production function model, with import inputs being complementary to skilled labors, and substitutable to unskilled labors. By exploiting China's higher education expansion as a quasi-natural experiment, this paper accurately examines the causal effect of the human capital expansion on the domestic value-added in exports. The results show that human capital expansion has negative effects on the domestic value-added in exports, and this result is driven by import inputs increase and processing trade engagement. We also find that the effect is more prominent for processing trade, foreign-invested firms, high-tech firms and disciplines of science and engineering.

1. Introduction

The world economy has entered the era of global value chain, in which products are jointly completed by many countries in the global scale. By China's accession to the World Trade Organization (WTO), Chinese firms have achieved the exceptional acceleration of export growth and economic growth. Under the pervasiveness of intra-production division, only by understanding trade gains from trade volume can be misleading. A multitude of existing literatures investigate China's trade pattern from domestic value added in exports (e.g., Dean et al., 2011; Johnson & Noguera, 2012; Koopman et al., 2012). While existing research points out that domestic value-added in exports has been declining in most countries, China's domestic value-added in exports has increased from 65% in 2000 to 70% in 2007 (Kee & Tang, 2016). Against the global value chain (GVC) context, shedding light on the role that public policy plays in the domestic added value of exports can be meaningful.

This paper explores the link between human capital intensity and the domestic value-added rate in exports of Chinese manufacturing firms and investigates its mechanism. Over the past 30 years, China's average years of schooling have experienced massive increase from 3.7 to 7.5. China's colleges and universities have expanded their enrollment on a large scale in 1999, known as China's higher education expansion. China's higher education expansion promotes human capital accumulation massively, and it is a relatively clean experiment allowing us to evaluate the causal effect of human capital expansion. By employing difference-in-difference (DID) approach, we take advantage of higher education expansion as a quasi-natural experiment to evaluate the causal impact of

* Corresponding author.
E-mail address: liyfphd@ruc.edu.cn (Y. Li).

https://doi.org/10.1016/j.asieco.2023.101621
Received 12 April 2022; Received in revised form 25 February 2023; Accepted 20 April 2023
Available online 26 April 2023

human capital expansion on the domestic value-added rate in exports.

This paper's contribution to the existing research is threefold. First, we provide micro-level evidence on the link between human capital intensity and the domestic value-added rate in exports of Chinese manufacturing firms. Second, we clearly investigate the mechanism of human capital expansion on the domestic value-added rate in exports from import inputs and processing trade. Third, we further provide heterogenous evidence on the effect of human capital expansion.

Our study is related to at least four strands of literature. First, this paper enriches the understanding of human capital. In the theory of endogenous growth, human capital mainly promotes economic growth through two ways. The first attributes economic growth to human capital accumulation and holds that the long-term sustainable economic growth comes from the continuous growth of human capital (e.g., Romer, 1986; Lucas, 1988). The second deems that human capital promotes economic growth by enhancing technological progress (e.g., Nelson & Phelps, 1966; Romer, 1990). Traditional human capital studies mainly focus on the impact of human capital on personal development and economic growth (e.g., Acemoglu, 1996, 1998). And some studies have linked human capital accumulation to trade exposure recently. Atkin (2016) finds that export exposure stemming from trade liberalization does lead to the increase in high school drop-out rate in Mexico. Li (2018) suggests that export expansion can influence skill supply directly and skill-acquisition decisions.

Another strand of literature studying the measurement of the domestic value-added rate in exports. Domestic value-added rate effectively measures the domestic content in exports export (Johnson & Noguera, 2012), which provides crucial understanding of domestic contribution to the trade growth. Hummels et al. (2001) calculate the value-added rate in exports by industry input-output (IO) tables for the first time across countries, the measurement of which has later been improved by some literatures (e.g., Dean et al., 2011; Koopman et al., 2012). By micro-level data in China, Upward et al. (2013) complement the IO-based estimates and calculate firms' domestic value-added rate over the period 2003–2006. Considering the measurement error caused by indirect trade and import inputs, Kee and Tang (2016) further calculate firms' domestic value-added rate over the period 2000–2006. Following Kee and Tang (2016), this paper measures firms' domestic value-added rate over 2000–2013.

Based on the measurement of the domestic value-added rate, a multitude of literatures explore its determinants. Most of the existing literatures focus on country-specific policy, such as trade policy, economic development and reform (e.g., Koopman et al., 2012; Kee & Tang, 2016; Aichele & Heiland, 2018; Ludema et al., 2021; Lu et al., 2022). Kee and Tang (2016) find that China's accession to WTO contributes massively to the rising of firms' domestic value-added rate. Lu et al. (2022) suggest that foreign investment liberalization does negative effect on firms' domestic value-added rate. Koopman et al. (2012) find that firms' domestic value-added rate in exports is higher in technology-intensive industries and developed economies. Other literatures concern about firm-level characteristics. Upward et al. (2013) suggest that processing trade firms tend to have a lower level of the domestic value-added rate in exports. Vrh (2019) points out that foreign-invested firms have demonstrated lower domestic value-added rate. However, existing literatures ignore the impact of human capital on the domestic value-added rate in exports.

By employing the higher education expansion in 1999, some literatures have focused on the effect of human capital on trade pattern. By virtue of the heterogeneous expansion of human capital across industries, Che et al. (2018) find that human capital expansion significantly promotes the firms' export, both from intensive and the extensive margins. Zhou et al. (2019) take advantage of the heterogeneous impact of higher education expansion across cities, and find that human capital expansion improves the export technology complexity by skills' agglomeration and technology carrier. Wu et al. (2021) show that human capital expansion promotes global value chain position upgrading, the finding of which relates mostly to our study. Other studies have exploited the impact of higher education expansion on labor force (e.g., Li et al., 2017; Knight et al., 2017; Lu & Zhang, 2019; Dai et al., 2021; Huang et al., 2022; Fu et al., 2022). For example, Li et al. (2017) find that higher education expansion leads to increased college premium for senior graduates and decreased college premium for younger graduates. Knight et al. (2017) suggest a negative relationship between higher education expansion and wages, employment and access to good jobs. Dai et al. (2021) find that each additional year of higher education allows monthly wage income to increase by 21%. By taking advantage of China's higher education expansion in 1999, this study employs the DID approach to evaluate the causal effect of human capital expansion on the domestic value-added rate in exports.

The remainder of the paper is as follows: the second part sets up a nested CES production function model to explore link between human capital expansion and the domestic value-added rate in exports; the third part introduces the background and identification method; the fourth part describes the data and variables; the fifth part represents the results of baseline regression and robustness test; the sixth part discusses the mechanism of human capital expansion on the domestic value-added rate in exports; the seventh part examines the heterogeneity effect of human capital on the domestic value-added rate in exports; the last part is the conclusion of this study.

2. Setup of the model

2.1. Model setup

To examine the link between an increase in skilled labor and domestic value-added rate in exports, we construct a nested CES production function model, with import inputs being complementary to skilled labors, and substitutable to unskilled labors (Lewis, 2011; Lafortune et al., 2019; Fan, 2019). We assume that firm produces gross output with labor and intermediate inputs. And we

introduce skilled and unskilled labor separately, with E^h standing for skilled labor and E^l standing for unskilled labor. Our production function also distinguishes import inputs (I) from domestic inputs (D).[1] Specifically, the production function is:

$$E^{\mathrm{eh}} = \left[(1-\eta_1)^{\frac{1}{\rho_1}}(I)^{\frac{\rho_1-1}{\rho_1}} + (\eta_1)^{\frac{1}{\rho_1}}\left(E^h\right)^{\frac{\rho_1-1}{\rho_1}}\right]^{\frac{\rho_1}{\rho_1-1}} \tag{1}$$

$$E^{\mathrm{el}} = \left[(1-\eta_2)^{\frac{1}{\rho_2}}(D)^{\frac{\rho_2-1}{\rho_2}} + (\eta_2)^{\frac{1}{\rho_2}}\left(E^l\right)^{\frac{\rho_2-1}{\rho_2}}\right]^{\frac{\rho_2}{\rho_2-1}} \tag{2}$$

$$E = \left[(1-\eta_3)^{\frac{1}{\rho_3}}\left(E^{eh}\right)^{\frac{\rho_3-1}{\rho_3}} + (\eta_3)^{\frac{1}{\rho_3}}\left(E^{el}\right)^{\frac{\rho_3-1}{\rho_3}}\right]^{\frac{\rho_3}{\rho_3-1}} \tag{3}$$

Where E^{eh} denotes intermediate output with skilled labor and import inputs, and E^{el} denotes intermediate output with unskilled labor and domestic inputs. E represents the final output. The elasticity of substitution sets as ρ_1, ρ_2 and ρ_3. And factor share of differentiated inputs is defined asη_1, η_2 and η_3, respectively.

We then define P^I as the unit price for import inputs and P^D as the unit price for domestic inputs. W^h and W^l denote the wage for skilled labor and unskilled labor, respectively. W^{eh} and W^{el} denote the unit price for differentiated output. And W represents the unit price for gross output.

$$W^{\mathrm{eh}} = \left[(1-\eta_1)\left(P^I\right)^{1-\rho_1} + (\eta_1)\left(W^h\right)^{1-\rho_1}\right]^{\frac{1}{1-\rho_1}} \tag{4}$$

$$W^{\mathrm{el}} = \left[(1-\eta_2)\left(P^D\right)^{1-\rho_2} + (\eta_2)\left(W^l\right)^{1-\rho_2}\right]^{\frac{1}{1-\rho_2}} \tag{5}$$

$$W = \left[(1-\eta_3)\left(W^{eh}\right)^{1-\rho_3} + (\eta_3)\left(W^{el}\right)^{1-\rho_3}\right]^{\frac{1}{1-\rho_3}} \tag{6}$$

Under assumptions of cost-minimization, the optimal factor demands are given by:

$$\frac{P^I}{W^h}\frac{I}{E^h} = \left(\frac{P^I}{W^h}\right)^{1-\rho_1}\frac{1-\eta_1}{\eta_1} \tag{7}$$

$$\frac{P^D}{W^l}\frac{D}{E^l} = \left(\frac{P^D}{W^l}\right)^{1-\rho_2}\frac{1-\eta_2}{\eta_2} \tag{8}$$

$$\frac{W^{eh}}{W^{\mathrm{el}}}\frac{E^{eh}}{E^{el}} = \left(\frac{W^{eh}}{W^{\mathrm{el}}}\right)^{1-\rho_3}\frac{1-\eta_3}{\eta_3} \tag{9}$$

2.2. Theoretical hypothesis

The foreign value-added rate in exports[2] is:

$$FVAR = \frac{P^I I}{W^h E^h + W^l E^l + P^D D + P^I I} \tag{10}$$

Where $P^I I$ is the foreign value-added in exports, and $W^h E^h + W^l E^l + P^D D$ is the domestic value-added in exports.

Eq. (10) can also be defined as:

[1] The production function here is simplified, and the setup does not affect our main conclusion.

[2] $VA = FVA + DVA$.

$$
\begin{aligned}
FVAR &= \frac{P^I I}{W^h E^h + P^I I} \times \frac{W^h E^h + P^I I}{W^h E^h + P^I I + W^l E^l + P^D D} \\
&= \frac{\frac{P^I I}{W^h E^h}}{\frac{P^I I}{W^h E^h} + 1} \times \frac{W^{eh} E^{eh}}{W^{eh} E^{eh} + W^{el} E^{el}} \\
&= \frac{\frac{P^I I}{W^h E^h}}{\frac{P^I I}{W^h E^h} + 1} \times \frac{\frac{W^{eh} E^{eh}}{W^{el} E^{el}}}{\frac{W^{eh} E^{eh}}{W^{el} E^{el}} + 1}
\end{aligned} \tag{11}
$$

Combining (7) and (9) into (11), we can get:

$$
FVAR = \frac{\frac{P^I I}{W^h E^h}}{\frac{P^I I}{W^h E^h} + 1} \times \frac{\frac{W^{eh} E^{eh}}{W^{el} E^{el}}}{\frac{W^{eh} E^{eh}}{W^{el} E^{el}} + 1} = \frac{\left(\frac{P^I}{W_h}\right)^{1-\rho_1} \frac{1-\eta_1}{\eta_1}}{\left(\frac{P^I}{W_h}\right)^{1-\rho_1} \frac{1-\eta_1}{\eta_1} + 1} \times \frac{\left(\frac{W^{eh}}{W^{el}}\right)^{1-\rho_3} \frac{1-\eta_3}{\eta_3}}{\left(\frac{W^{eh}}{W^{el}}\right)^{1-\rho_3} \frac{1-\eta_3}{\eta_3} + 1} \tag{12}
$$

Assuming that $W^l = 1$, P^I and P^D remain unchanged, skilled labor increases and W^h decreases. Eq. (12) shows that the relationship between foreign value-added and skilled labor depends on the elasticity of substitution between skilled labor and import inputs ρ_1 and the elasticity of substitution between unskilled labor and import inputs ρ_3.

It is believed that the quality of import inputs is generally higher than that of domestic inputs. Firms using import inputs are highly possible to correspondingly produce with skilled labor. This is because skilled labor is usually required to absorb the technology embodied in import inputs. In other words, import inputs are complementary to skilled labor and substitutable to unskilled labor. Therefore, $\rho_1 < 1$ denotes a complementary relationship between import inputs and skilled labor, $\rho_3 > 1$ denotes a substitution relationship between import inputs and unskilled labor.

It is manifest from the Eq. (12) that, while skilled labor increases, $\left(\frac{P^I}{W^h}\right)^{1-\rho_1}$ rises, $\left(\frac{W^{eh}}{W^{el}}\right)^{1-\rho_3}$ descends, $\frac{\left(\frac{P^I}{W_h}\right)^{1-\rho_1} \frac{1-\eta_1}{\eta_1}}{\left(\frac{P^I}{W_h}\right)^{1-\rho_1} \frac{1-\eta_1}{\eta_1} + 1}$ and $\frac{\left(\frac{W^{el}}{W^{el}}\right)^{1-\rho_3} \frac{1-\eta_3}{\eta_3}}{\left(\frac{W^{el}}{W^{el}}\right)^{1-\rho_3} \frac{1-\eta_3}{\eta_3} + 1}$ ascend. Hence, foreign value-added rate increases and domestic value-added rate decreases.

Therefore, we propose the hypothesis: given other conditions, while skilled labor increases, domestic value-added rate in exports decreases.

3. Background and identification

3.1. Background

The National Collage Entrance Examination (Gaokao) is the most important channel for selecting students. Since the founding of the People's Republic of China, the central government has played a dominant role in the higher education institutional reform. Compared with other countries, the proportion of the population attending colleges and universities before 1999 in China was still at a

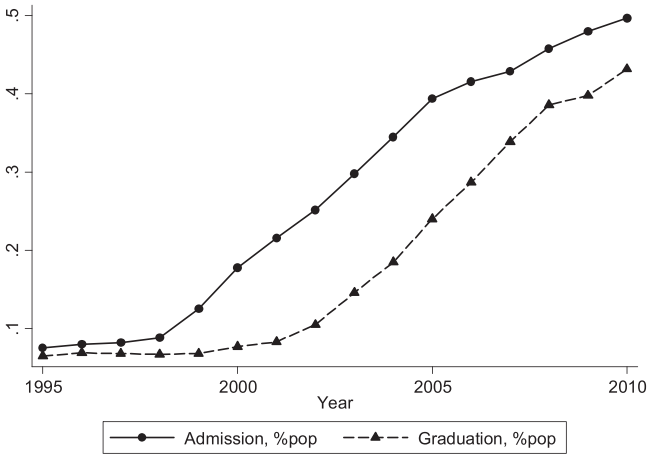

Fig. 1. College admission and graduation in China from 1995 to 2010. Note: The data comes from China Education Yearbook.

low level. According to World Bank, China's admission rate of higher education in the mid-1990 s was much lower than other economics, such as India and Thailand. Additionally, owing to the fact that a multitude of state-owned enterprises lead to a massive amount of unemployment from 1990 s and due to the economic shrinkage caused by Asian financial crisis, some scholars and researchers actively promote higher education enrollment. Under the circumstances, the Chinese government issued the Action Plan for Revitalizing Education for the 21st Century in June 1999, the goal of which was rising enrollment rate of higher education to 11% in 2000 and 15% in 2010 (Xiong et al., 2022).

The implementation of higher education expansion has contributed massively to higher education enrollment. As shown in Fig. 1, higher education admission as percentage of population clinked steadily over the period from 1995 to 1998. Specifically, admission rate has experienced an enormous surge since 1999. For higher education graduation as percentage of population, the line graph has demonstrated a sharp increase since 2002. Therefore, higher education expansion since 1999 has provided a quasi-natural experiment, which enables us to evaluate the causal effects of human capital expansion on the domestic value-added rate in exports in China. To be specific, the goal of higher education graduation is to increase the higher education enrollment in China and not targeted at specific industries, which has exogenous variation across industries. Moreover, since higher education expansion has issued by central government, it's difficult for firms to form effective expectation before higher education expansion. Thus, higher education expansion provides a quasi-natural experiment, which ensures us to rigorously evaluate the causal effects of human capital expansion on the domestic value-added rate in exports in China (Che & Zhang, 2017; Che et al., 2018).

3.2. Empirical framework

We examine the link between human capital intensity and the domestic value-added rate in exports of Chinese manufacturing firms. By exploiting China's higher education expansion in 1999, we employ DID approach to evaluate the causal effect of human capital expansion on the domestic value-added rate in exports. The DID approach can alleviate endogeneity by reducing controls which need to be considered (Angrist & Pischke, 2008). By virtue of the fact that human capital intensity is different across industries, the impact of human capital expansion brought by higher education expansion is different across industries, which enables us to conduct the DID approach (Che & Zhang, 2017; Che et al., 2018). Based on our empirical identification, we estimate the following equation:

$$DVAR_{ijt} = \beta HC_j \times POST02_t + \alpha_i + \gamma_t + \sigma X_{ijt} + \varepsilon_{ijt} \tag{13}$$

where $DVAR_{ijt}$ denotes the export domestic value-added rate for firm i in industry j at year t. $POST02_t$ is a dummy variable, taking a value of 0 for 2000–2001 and 1 for 2002–2013. HC_j is the human capital intensity in industry j. To be specific, we use the proportion of workers with bachelor degree or above of the USA in 1980 to represent that of our country. The premise is that (1) technological level of the USA in 1970 s can comprehensively represent that of world; (2) average human capital intensity of the USA in 1980 is highly correlated with that of China in 1995 and 2004. α_i and γ_t represent firm fixed effect and year fixed effect, respectively. We also control a series of firm-level variables and initial industry-level characteristics X_{ijt}. And ε_{ijt} is the error term.

Our main parameter of interest is β, which represents the differences between change of the domestic value-added rate in exports of high HC-intensive industries and that of the low HC-intensive industries before and after higher education expansion. A positive sign of β means that human capital expansion enables to promote the domestic value-added rate in exports, and a negative sign of β indicates that human capital expansion poses negative effects on the domestic value-added rate in exports.

4. Data and variable

4.1. Data

Our main datasets come from the Annual Surveys of Industrial Firms (ASIF) and the China Customs Database (CCD) over the 2000–2013 period. The ASIF includes all state-owned and non-state-owned firms with annual sales over 5 million Yuan (for 2011–2013 over 20 million Yuan), which is a comprehensively micro-level dataset in China. Following Brandt et al. (2012), we conduct data processing. For industry, we unify 4-digit classification to GB/T4754–2011. And we get rid of observations with absence of sales, workforce, total assets or fixed assets. Moreover, we exclude observations with abnormal value for key variables, such as total assets less than current assets and total assets less than net fixed assets. Meanwhile, we only select manufacture for research. The CCD provide transactions on import and export by Chinese firms, which contains detailed information such as value, quantity and destination countries at the HS 8-digit level. And we aggregate gross value to HS 6-digit level. Since the ASIF enables us to obtain firm-level characteristics, we merge the CCD with the ASIF based on firms' name-year and contact information (Upward et al., 2013).

Another dataset is the World Input-Output Data (WIOD), which enables us to measure the proportion of domestic value-added rate that is returned and absorbed by China and repeatedly calculated (Wang et al., 2013). For industry, we merge its classification with the 2-digit Chinese Industrial Classification (CIC). What's more, we also use Chinese City Statistical Yearbook and Chinese Patent Database to check robustness results and possible mechanism.

4.2. Variables

4.2.1. DVAR

Based on above two firm-level datasets over the 2000–2013 period, we calculate firms' domestic value-added rate in exports.

Considering the problem of intermediate trade agents, import inputs and capital depreciation, the domestic value-added rate in exports can be defined as (Kee & Tang, 2016):

$$DVAR_{ijtk} = \begin{cases} 1 - \dfrac{IMP_{ijt}^{BEC}}{Y_{ijt}} - \dfrac{10.96\%K_{ijt}}{Y_{ijt}} + RDV_{jt} - PDC_{jt}, k = 1 \\ 1 - \dfrac{IMP_{ijt}}{Y_{ijt}} - \dfrac{10.96\%K_{ijt}}{Y_{ijt}} + RDV_{jt} - PDC_{jt}, k = 2 \\ \omega_1 \left(1 - \dfrac{IMP_{ijt}^{BEC}}{Y_{ijt}}\right) + \omega_2 \left(1 - \dfrac{IMP_{ijt}}{Y_{ijt}}\right) - \dfrac{10.96\%K_{ijt}}{Y_{ijt}} + RDV_{jt} - PDC_{jt}, k = 3 \end{cases} \tag{14}$$

Where $DVAR_{ijtk}$ is our measure of the domestic value-added rate by trade mode k of firm i in industry j at year t. $k = 1$, $k = 2$ and $k = 3$ represent general trade, processing trade and mixed trade, respectively. Y_{ijt} denotes the output of firm i.. is the value of import capital goods. Since its depreciation can lead to the overvaluation of the domestic value-added rate, we adjust value of import capital goods by setting depreciation rate at 10.96%. IMP_{ijt} and IMP_{ijt}^{BEC} denote the gross value of import goods and import inputs, which are entirely used by processing trade (Upward et al., 2013). To be specific, BEC refers to Broad Economic Categories. And we identify intermediate goods which belong to BEC groups 111, 121, 21, 22, 31, 322, 42 and 53. ω_1 and ω_2 capture the ratio of general trade and processing trade relative to mixed trade.

Following Wang et al. (2013), we adjust the domestic value-added rate by WIOD database. RDV_{jt} is the proportion of domestic value-added rate that is returned and absorbed by China, and.. is domestic value-added rate repeatedly calculated. By identifying trade agent, we adjust trade value by identifying trade agents, and we exclude the observations with excessive value for import and export (Ahn et al., 2011).

4.2.2. Human capital intensity

We follow Ciccone and Papaioannou (2009) in measuring human capital intensity. To be specific, Ciccone and Papaioannou (2009) defines human capital intensity as the proportion of workers with bachelor degree or above in 3-digit International Standard Industrial Classification (ISIC). We then match it with the 4-digit Chinese Industrial Classification (CIC) based on HS 6-digit code. We therefore obtain the human capital intensity of 4-digit CIC in China. Summary statistics of main variables are demonstrated in Table 1.

4.3. Graphical evidence of relative trend in DVAR

In Fig. 2, we present the correlation between the human capital and the domestic value-added rate in exports during the period 2000–2013. The Fig. 2 demonstrates the time trend of the domestic value-added rate in human capital intensity across industries. To be specific, we show differential trends of the domestic value-added rate in exports of the above-median HC-intensity industries versus below-median HC-intensity industries. For the period 2000–2002, the domestic value-added rate in exports of two groups clinks steadily and shows similar trend. And for 2003–2013, the trend of the below-median HC-intensity group demonstrates a greater growth compared with that of the above-median HC-intensity, which means that there might be a negative correlation between human capital expansion and the domestic value-added rate in exports. Moreover, Fig. 2 leads support to the identifying assumption of the DID approach, which can prove that the differences between two groups' trends are not cause by factors other than the human capital expansion.

5. Empirical analyses

5.1. Benchmark regression

Table 2 reports the regression estimates of Eq. (13). To be specific, only including time fixed effect and firm fixed effect, we find the estimated coefficient of $HC_j \times POST02_t$ is statistically significant and negative in Column (1). In Column (2), we further include time-

Table 1
Summary statistics of main variables.

	Variable	Meaning	Obs	Means	Std.dev	Min	Max
Dependent variable	$DVAR_{ijt}$	*Domestic value-added rate of exports*	585,499	0.878	0.179	0.000	0.998
Independent variable	HC_j	*Human capital intensity*	229	0.132	0.054	0.037	0.270
Firm-level controls	$size_{ijt}$	*Firm size*	585,499	5.435	1.132	2.079	12.316
	age_{ijt}	*Firm age*	584,895	2.111	0.674	0.000	5.136
	$ratio_{ijt}$	*Factor structure of firm*	585,499	3.837	1.468	-6.265	13.957
	SOE_{ijt}	*Dummy variable of state-owned firm*	585,499	0.276	0.447	0.000	1.000
	$foreign_{ijt}$	*Dummy variable of foreign-invested firm*	585,499	0.317	0.465	0.000	1.000
Initial industry characteristics	$capint_{jt}$	*Capital intensity*	229	1.358	0.546	0.443	3.194
	$finance_{jt}$	*External Finance*	229	0.352	0.279	-0.450	1.140
	$contract_{jt}$	*Contract Enforcement*	229	0.513	0.198	0.058	0.859

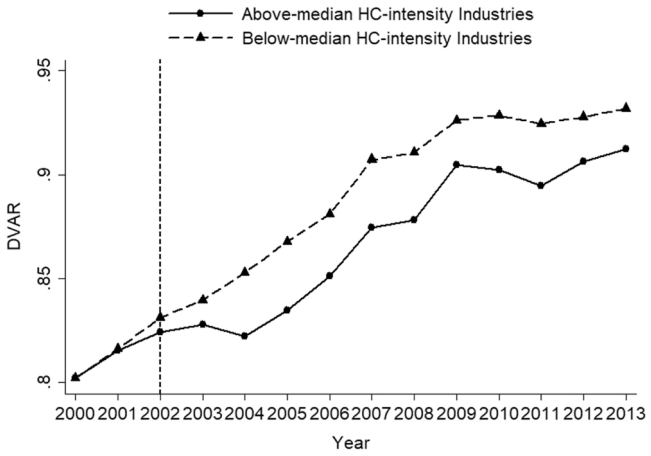

Fig. 2. Domestic value-added rate in exports by human capital intensity.

Table 2
The average effects of human capital expansion on domestic value-added rate of firms' exports.

Dependent: DVAR	(1)	(2)
$HC_j \times POST02_t$	-0.1488***	-0.1885***
	(0.0268)	(0.0351)
Firm-level controls	No	Yes
Industry-level controls	No	Yes
Year fixed effect	Yes	Yes
Firm fixed effect	Yes	Yes
R^2	0.7615	0.7631
Obs	289,446	289,166

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

varying variables at firm level and industry-level characteristics. Clearly, estimated coefficient for $HC_j \times POST02_t$ is still statistically significant and negative. The regression results indicate that after human capital expansion, the domestic value-added rate in exports of the group with below-median HC-intensity demonstrates a greater growth compared with that of the above-median HC-intensity, which in other words means that human capital expansion has negative effects on domestic value-added rate in exports. The possible explanation is that although the domestic value-added rate in exports of two groups grows in both types of industries. The trend of the below-median HC-intensity group demonstrates a greater growth compared with that of the above-median HC-intensity, which can attribute to the catch-up effect, and the empirical result means that there might be a negative correlation between human capital expansion and the domestic value-added rate in exports.

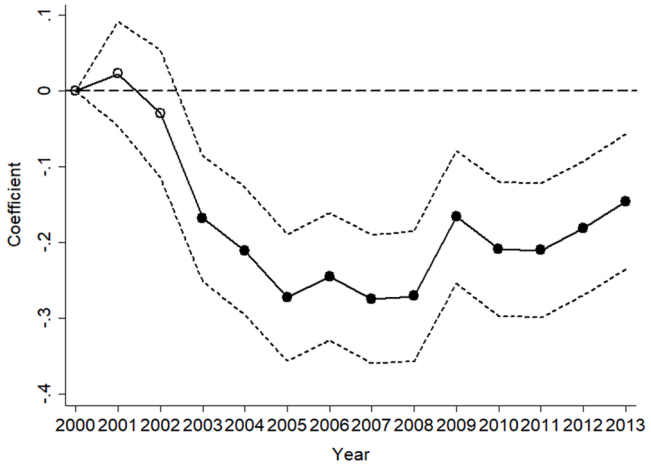

Fig. 3. the dynamic effect of the human capital expansion on domestic value-added rate in exports.

In addition, in order to estimate the dynamic effect of the human capital expansion on domestic value-added rate in exports, we further add interaction terms between the HC_j and the year dummies from 2001 to 2013 to Eq. (13). The estimated coefficients are drawn in Fig. 3. Notably, before 2002, the estimated coefficient is relatively small and mostly insignificant. After 2002, it becomes negative and statistically significant. To be more accurate, the coefficient declines gradually from 2002, shrinking from the zenith and followed by a bounce. Notably, the results more accurately demonstrate that this paper satisfies the parallel trend assumption.

5.2. Identification hypothesis test

The validity of the DID estimates relying on some identifying assumptions: (1) firms have not formed expectations before the human capital expansion; (2) other policy reform has not differentially affected our treatment group and control group. In this section, to corroborate identifying assumptions, we exploit a great many identification hypothesis tests by including expectation effect, excluding other confounding policy effects, introducing industry-specific time trend and making placebo test to confirm the validity of our specification.

5.2.1. Expectation effect

To further check if firms have formed expectations before the human capital expansion, we include the interaction $HC_j \times D01_t$ to the Eq. (13). The premise is that if there is no expectation, the estimation coefficient of $HC_j \times D01_t$ is insignificant. It is clear from the Column (1) of Table 3 that the estimation coefficient of $HC_j \times D01_t$ is insignificant and really small, while that of the $HC_j \times POST02_t$ is still statistically significant and negative. It indicates that there is no expectation effect before human capital expansion and the policy of college enrollment expansion is relatively exogenous.

5.2.2. Excluding other policy effects

To make sure that our estimation results only capture the effect of human capital expansion, we do the robust check by excluding other confounding policy effect around 2002. The regression results are represented in Column (2)-(6) of Table 3. Firstly, the fact that China joined the WTO in 2001 was accompanied with tariff reduction, which brought competitive effect and cost effect. We deal with this problem by introducing industrial output tariffs and input tariffs respectively. The empirical results are in Column (2) and (3) of Table 3. Manifestly, the coefficients of tariff are relatively small, while the estimation coefficient of the. is still statistically significant and negative. What's more, jointing the WTO can also leads to a reduction of foreign tariffs at the same time, we thus further introduce foreign tariffs and do the robust check. Column (4) shows that the estimation result is robust. Next, that China joined the WTO was also with the relaxation of foreign direct investment (FDI) regulations, which might have differentiated effects on the treatment group and

Table 3
Checks on the identifying assumptions.

Dependent: DVAR	(1) Expectation effect	(2) Output tariffs	(3) Input tariffs	(4) External tariffs	(5) Output share of FOEs	(6) Output share of SOEs	(7) Industry-specific time trend	(8) Placebo test
$HC_j \times POST02_t$	-0.1923***	-0.2118***	-0.2140***	-0.1953***	-0.1893***	-0.1898***	-0.1118**	-0.0022
	(0.0391)	(0.0371)	(0.0375)	(0.0357)	(0.0352)	(0.0350)	(0.0492)	(0.0208)
$HC_j \times D01_t$	0.0064							
	(0.0344)							
Industry output tariffs		-0.0005**						
		(0.0002)						
Industry input tariffs			-0.0013**					
			(0.0006)					
Industry external tariffs				-0.0007***				
				(0.0002)				
Output share of FOEs					0.0266***			
					(0.0086)			
Output share of SOEs						0.1162***		
						(0.0099)		
Industry-specific time trend	No	No	No	No	No	No	Yes	No
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.7631	0.7636	0.7644	0.7630	0.7631	0.7636	0.7642	0.7630
Obs	289,166	274,022	270,027	284,286	289,166	289,166	289,166	289,166

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

control group and thus consequently bias the estimate. Therefore, we further include the industrial foreign share. Column (5) demonstrates that estimation result of human capital expansion is still robust. What's more, there is a reform of state-owned firms (SOEs) in 1990 s, including a large-scale privatization, close-down of small SOEs, and an improvement in the efficiency of surviving (large) SOEs. In terms of coping with this problem, we further include the industrial SOE share. The empirical result is in Column (6), which indicates that the SOE reform does not affect our baseline results. In conclusion the robust checks of excluding other policy effects show that our baseline results are not caused by other policies other than the human capital expansion.

5.2.3. Industry-specific time trend

That unobserved industry characteristics may correlate the core interaction term can bias the estimation coefficient. Normally, this issue can be coped with by including industry-time fixed effect. However, the core interaction is at the industry-time level, it's therefore impossible for us to add industry-time fixed effect to control time-varying and industry-varying unobserved factors. Therefore, referring Liu and Qiu (2016), we add to Eq. (13) the industry-specific time trend to control all unobserved industry characteristics if they affect firms' domestic value-added rate in linear time trend. The regression result is presented in Column (7) of Table 3. It is manifest that the core interaction shows no great changes and our estimation results are not driven by any unobserved industry time trends.

5.2.4. Placebo test

To corroborate that unobserved factors do not bias our estimation result, we do the placebo test further. To be specific, we randomly select one year from 2001 to 2013 as the actual year of policy chock and human capital intensity is randomly allocated to industries. After operating the coefficient estimation 500 times, we can get the coefficient of the random interaction term $HC_j^{random} \times POST_t^{random}$ on average. The distribution of $\widehat{\beta}^{random}$ is depicted in Fig. 4 and the regression result is represented in Table 3 Column (8). It shows that the coefficient estimation of $\widehat{\beta}^{random}$ is insignificant and far from the baseline result. The result indirectly indicates that unobserved factors do not disturb our estimation result.

5.3. Robustness test

5.3.1. Two periods estimation

The fact that multi-period estimation exaggerates significance can lead to an upward bias in our coefficient estimation (Bertrand et al., 2004). Hence, as a robust check, we collapse the panel structure into two periods, one before human capital expansion (2000–2001) and the other after human capital expansion (2002–2013). And then we operate the coefficient estimation. Meanwhile, this exercise enables us to be aware of the long-term average effect of human capital expansion on the domestic value-added rate of firms' exports. The estimation result is demonstrated in Table 4 Column (1), which corroborates the negative effect of human capital expansion on the domestic value-added rate of firms' exports.

5.3.2. City-year fixed effect

Compared with other countries, China's economic system is highly decentralized. Local government officials are evaluated by economic growth, therefore they have incentives to implement industrial policies appropriate to the local economic structure (Xu, 2011). Normally, for regions with HC-intensive industries, government officials always have the stimulation to develop HC-intensive industries for the purpose of promoting local economic growth. To address the concern that our estimation result might be driven by time-varying regional factors, we further include city-year fixed effect and operate the estimation. As shown in Table 4 Column (2), our

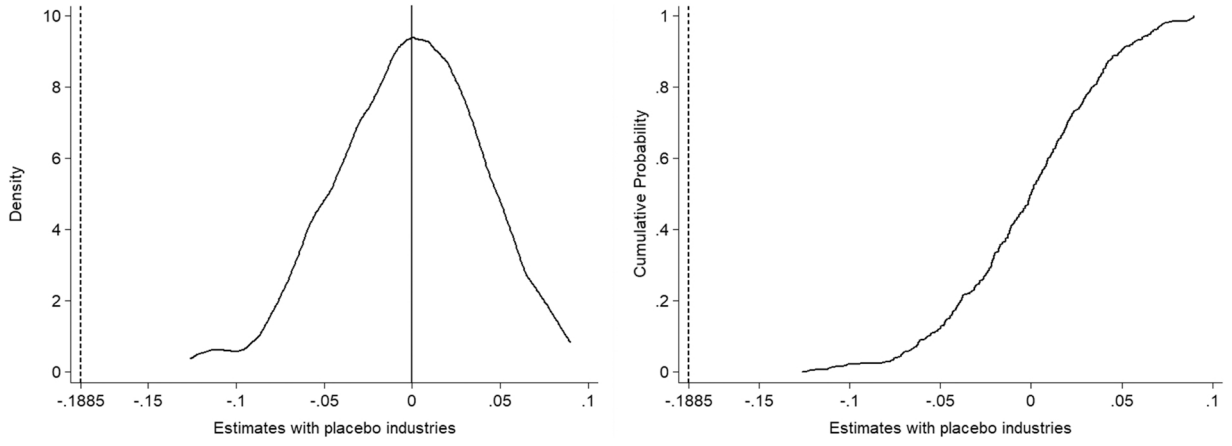

Fig. 4. Distribution of estimated coefficients after 500 simulations. Note: The left figure shows the density distribution and the right figure shows the cumulative density distribution.

Table 4
Other robustness checks.

Dependent: DVAR	(1) Two periods estimation	(2) City-Year fixed effect	(3) Controls lagged	(4) Redefine$POST02_t$	(5) Redefine policy shock time	(6) Reconstruction of *HC*
$HC_j \times POST02_t$	-0.1429***	-0.1643***	-0.1609***	-0.2492***		-0.1577***
	(0.0398)	(0.0287)	(0.0414)	(0.0358)		(0.0359)
$HC_j \times POST03_t$					-0.1834 * **	
					(0.0358)	
Lagged controls	No	No	Yes	No	No	No
City-Year fixed effect	No	Yes	No	No	No	No
Firm-level controls	Yes	No	No	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.9506	0.7556	0.7786	0.7632	0.7633	0.7630
Obs	85,085	263,332	189,608	289,166	289,415	289,166
Dependent:DVAR	(7) DVAR at industry level	(8) Winsor	(9) Firms with sales above 20 million	(10) Samples before 2008	(11) Panel tobit	(12) Different cluster types
$HC_j \times POST02_t$	-0.2722***	-0.1848***	-0.1964***	-0.1404***	-0.1693***	-0.1898
		(0.0317)	(0.0358)	(0.0431)	(0.0114)	(0.0577 ***)
						[0.0300 * **]
						{0.0584 * ** }
Firm-level controls	(0.0321)	Yes	Yes	Yes	Yes	Yes
Industry-level controls		Yes	Yes	Yes	Yes	Yes
Year fixed effect	No	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	No	Yes	Yes	Yes	Yes	Yes
R^2	Yes	0.7631	0.7637	0.8279		0.7631
Wald	Yes				33,445.16***	
Log likelihood	Yes				173,010.41	
Obs	Yes	283,517	284,819	139,756	289,166	289,166

Note: standard error in column (1) is the 100 times of Bootstrap adjustment. Standard errors of column (12) in the parentheses, square bracket and brace are clustered at the industry, province-industry and city-industry level, respectively.

result is robust to the inclusion of city-year fixed effect, suggesting that our finding is not driven by time-varying factors at city level.

5.3.3. Controls lagged by one period

One problem might be concerned is that human capital expansion can affect domestic value-added rate in exports through time-varying control variables (Angrist & Pischke, 2008). To cope with this issue, we lag the time-varying control variables by one period. As shown in Column (3) of Table 4, the core interaction term is negative and statistically significant, implying that our estimation result is still robust.

5.3.4. Policy shock reassignments

In our baseline regression, we identify 2002 as the time of human capital expansion. Since college graduates usually enter labor market only after getting their graduation certificates, human capital expansion actually occurred in July 2002. Hence, we redefine the value of.. To be specific, $POST02_t$ takes a value of 0 for 2000–2001, 1/2 for 2002 and 1 for 2003–2013. Column (4) of Table 4 shows that the estimation result is robust. Following Che and Zhang (2017), we take 2002 as the year of human capital expansion to study its effect on export performance in previous estimation. And there are also some literatures take 2003 as the year of policy shock. In order to take this concern into account, we change the policy shock time to 2003 and do the robust check. Column (5) demonstrates that our baseline estimation result is robust.

5.3.5. Alternative measures of human capital

Thus far, we use human capital intensity of the USA to represent that of China. To alleviate concerns about biased estimation, we conduct a robustness check using the human intensity calculated by Chinese Firm Census in 2004. The result is represented in Column (6) of Table 4. The coefficient estimation is negative and statistically significant, implying the result is robust.

5.3.6. DVAR at industry level

Input-output table is based on large enterprises, which can cause measurement error of our calculation of the domestic value-added rate. To cope with this problem, domestic value-added rate at firm level aggregates to the industry level. The regression estimation result is represented in Column (7) of Table 4. It shows that although the coefficient estimation decreases paltrily, our baseline result is

still robust.

5.3.7. Winsor

As there might be extreme values in the domestic value-added rate in exports, regression estimation can lead to biased coefficient estimation. To be specific, if there exists measurement error, the estimation result might be biased. Therefore, in order to alleviate measurement error, we winsorize the top and bottom 1% sample. The regression estimation is represented in Column (8) of Table 4. It shows that although the interaction term $HC_j \times POST02_t$ decreases paltrily, and the estimation result is still robust.

5.3.8. Exclusion of firms with annual sales below 20 million

The fact that the ASIF covers all SOEs and non-SOEs with sales over 5 million Yuan (20 million since 2011) can get rid of some samples, which can further bias the estimation result. To corroborate that our baseline result is not disturbed by the lack of firms with annual sales below 20 million, we focus on the sample with annual sales above 20 million. Regression estimation is reported in Column (9) of Table 4. Manifestly, our baseline result remains robust.

5.3.9. Samples before 2008

In addition, there might be other potential factors confusing our empirical estimation. For instance, the fact that New Law on Enterprise Income Tax came into effect on January 2008 might confuse the impact of human capital expansion on the domestic value-added rate of firms' exports. The new law adjusts a wide range of aspects in enterprise income tax, which will certainly affect firms' investment behaviors. Therefore, to confirm there are no other confounding policy effects after 2002, we operate the regression estimation again. To be specific, we get rid of the sample after 2008. The premise is that if there are no confounding policy effects after 2008, it should demonstrate significant effect of $HC_j \times POST02_t$ on domestic value-added rate in exports. The estimation result is presented in Column (10) of Table 4, which shows that the interaction term $HC_j \times POST02_t$ is negative and statistically significant.

5.3.10. Panel tobit

Thus far, we use the OLS method to estimate the effect of human capital expansion on the domestic value-added rate of firms' exports. However, the domestic value-added rate of firms' exports takes the value of 0–1. In other words, the dependent variable is restricted, thus our baseline estimation might be biased. Therefore, we operate the regression estimation using the panel tobit model again. Notably, we obtain very similar estimation result, as shown in Column (11) of Table 4. The estimation regression results show that estimation results of this paper do not vary with the different estimation method.

5.3.11. Different cluster types

Considering autocorrelation at firm level, the standard error is clustered at the firm level in baseline estimation. However, owing to the fact that core interaction term $HC_j \times POST02_t$ sets at the industry level, human capital expansion can lead to unobserved factors autocorrelation at the industry. To cope with this problem, we then cluster standard error at industry level. In addition, for robust check, we also cluster standard error at the industry-province level and industry-city level, so as to control autocorrelation at industry-province level and industry-city level. Estimation results are shown in Table 4 Column (12), coefficients of the core interaction term are at the 1% significance level and benchmark regression result is steady.

6. Mechanism

The previous study indicates that after human capital expansion, the domestic value-added rate of exports of the group with below-median HC-intensity demonstrates a greater growth compared with that of the above-median HC-intensity, which in other words

Table 5
Mechanism checks.

Dependent:	(1) Import volume	(2) Product categories	(3) Origin countries	(4) Average value	(5) Trade density	(6) DVAR	(7) Ratio of processing trade	(8) DVAR
$HC_j \times POST02_t$	1.1897**	6.4411*	-1.9900**	0.9625**	-0.0362	-0.2303***	0.2800***	-0.1596***
	(0.4888)	(3.6430)	(0.8222)	(0.4050)	(0.0661)	(0.0500)	(0.0730)	(0.0359)
Import volume						-0.0312***		
						(0.0006)		
Ratio of processing trade								-0.0830***
								(0.0016)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.8636	0.8896	0.8774	0.8346	0.7800	0.7759	0.5340	0.7750
Obs	145,742	145,742	145,742	145,742	145,742	145,742	270,697	270,697

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

means that human capital expansion has negative effects on the domestic value-added rate of exports. In this section, we provide further evidence to shed light on the mechanism of human capital expansion on the domestic value-added rate of firms' exports. The empirical specification is outlined as the following model:

$$Z_{ijt} = \beta_1 HC_j \times POST02_t + \alpha_i + \gamma_t + \sigma X_{ijt} + \varepsilon_{ijt} \tag{15}$$

$$DVAR_{ijt} = \beta_2 HC_j \times POST02_t + \alpha_i + \gamma_t + \sigma X_{ijt} + \lambda Z_{ijt} + \varepsilon_{ijt}. \tag{16}$$

where Z_{ijt} is the mediating variable. If β_1 and. are statistically significant, there exists mediating effect of Z_{ijt}. We investigate the mechanism of human capital expansion on the domestic value-added rate of firms' exports from three channels. Firstly, we investigate whether import inputs is promoted by human capital expansion, which is the direct evidence of domestic value-added rate decline. Second, processing trade can also be mechanism of human capital expansion on the domestic value-added rate of firms' exports. The premise is that, human capital expansion promotes firms to engage in processing trade and low value-added production links, further reducing the domestic value-added rate in exports.

6.1. Import inputs

This part explores the mechanism of human capital expansion on the domestic value-added rate of exports from firm's import behavior. The premise is that skilled labor expansion brought by the human capital expansion usually improves intermediate inputs quality, and the quality of import inputs is generally higher than that of the domestic (Bas & Strauss-Kahn, 2015). Therefore, we expect that after higher education expansion, human capital expansion has positive impact on firm's import (e.g., Vogel & Wagner, 2010; Kasahara & Lapham, 2013). To be specific, we explore the effect of human capital expansion on the import volume firstly. The regression result is represented in Column (1) of Table 5. The coefficient is positive and statistically significant, implying that human capital expansion can promote import inputs.

In addition, following the exercises of existing literatures, this paper performs the marginal decomposition of import volume. The specific decomposition is as follows:

$$\ln import_{it} = \ln variety_{it} + \ln origin_{it} + \ln \overline{import}_{it} + density_{it} \tag{17}$$

Where $import_{it}$ represents the volume of import inputs; $variety_{it}$ demonstrates the number of import categories; $origin_{it}$ defines as the number of import country of origin; $\overline{import}_{it}$ is the average import product value of firms; $density_{it}$ is the trade density of import inputs. Among them, the number of import categories and the number of import country of origin actually reflect the extensive margins of import, while the average import value denotes the intensity margin of import.

Regression results of decomposition are reported in Column (2)-(5) of Table 5. Specifically, column (2) reports estimation result with the number of import categories as dependent variable. The estimation coefficient of the core interaction term is significantly positive, implying that human capital expansion has significantly increased import categories. Column (3) shows that human capital expansion negatively affects the number of import country of origin. In addition, the increase of import input's unit price is actually its improvement of quality (e.g., Schott, 2004; Hummels & Klenow, 2005). Column (4) of Table 5 reports the regression results with the average import product value of firms as the dependent variable. It is manifest that human capital expansion has significantly positive effects on the average import product value of firms, indicating that human capital expansion promotes import inputs through the average import product value of firms. What's more, as is shown in Column (5) of Table 5, there is no significant effect of human capital expansion on trade density of firms.

Based on these, we further investigate whether increase of import inputs leads to the domestic value-added rate decline. The regression result is represented in Column (6) of Table 5. λ is negative and statistically significant, implying that import inputs have negative effects on the domestic value-added rate of firms' exports. In conclusion, the regression result indicates that human capital expansion has a negative impact on the domestic value-added rate of firms' exports through the increase of import inputs.

Table 6
Heterogeneous effects by trade modes and ownership.

Dependent: DVAR	Different Trade Modes		Different Ownership	
	(1) General trade	(2) Processing trade	(3) POEs and SOEs	(4) FOEs
.	0.0316	-0.2126***	-0.1219***	-0.1935***
	(0.0425)	(0.0609)	(0.0307)	(0.0466)
Firm-level controls	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
R^2	0.8560	0.7856	0.7804	0.7497
Obs	104,420	184,746	116,450	172,716

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

6.2. Processing trade

The third mechanism of human capital expansion on the domestic value-added rate of exports is the processing trade. The basic pattern of processing trade is conducting simple processing tasks with import inputs. Human capital expansion allows firms to promote the ratio of the processing trade to increase, which thus expands import inputs and further leads to lower level of the domestic value-added rate of firms' exports. Regression results are reported in Column (7)-(8) of Table 5. Manifestly, we find a positive and statistically significant effect of human capital expansion on the ratio of processing trade, indicating that human capital expansion enables to promote processing trade. What's more, λ is negative and statistically significant, implying that the ratio of processing trade has a negative effect on the domestic value-added rate of firms' exports. It is clearly that human capital expansion can promote processing trade and further reduces the domestic value-added rate of firms' exports.

7. Heterogeneous effects

In the previous sections, we have identified that human capital expansion has negative impacts on the domestic value-added rate of firms' exports. However, owing to differences in trade modes, ownership, factor intensity, technical complexity of firms and the academic field of cities, the domestic value-added rate of firms' exports might response to human capital expansion heterogeneously. In this section, we carry out a series of exercises to investigate whether the domestic value-added rate of firms' exports response to human capital expansion differently. The regression results are represented in Tables 6–8.

7.1. Heterogeneous effects by trade modes and ownership

The main form that China participates into GVCs is processing trade. From mid-1990 s to 2009, processing trade has accounted for more than a third of the China's exports. The production modes of processing trade are massively different from those of general trade. It has been found that the domestic value-added rate of processing trade is 50% lower than that of non-processing trade (Upward et al., 2013). Therefore, we explore whether the impacts of human capital expansion on the domestic value-added rate differ by trade modes. As is shown in Column (1)-(2) of Table 6, the impact of human capital expansion on the domestic value-added rate is significantly negative for processing trade, while the effect of human capital expansion on general trade is insignificant. The possible explanation is that, firms engaging in processing trade are more likely to participate into GVCs.

Due to the administrative intervention of China's factor market, firms of different ownership might response heterogeneously to human capital expansion. Hence, we explore heterogeneous effects based on firms' ownership. The regression results are represented in Column (3)-(4) of Table 6. Our estimation results indicate that human capital expansion has significantly negative impact on private-owned firms (POEs), state-owned firms (SOEs) and foreign-invested firms (FOEs), but the effect of the human capital expansion on foreign-invested firms is more prominent. The possible explanation is that, foreign-invested firms always have a better, deeper and wider understanding of the global market, or some foreign-invested firms are especially established for trade, therefore it is easier for foreign-invested firms to engage in international trade.

7.2. Heterogeneous effects by factor intensity and technical complexity

We explore whether the impacts of human capital expansion on the domestic value-added rate differ by firms' factor intensity. According to factor structure, we divide manufacture industries into 3 categories. To be specific, we divide 2-digit CIC industries of 13, 14, 15, 16, 17 and 22 into labor-intensive industries and 2-digit CIC industries of 25, 31, 32, 33, 34, 35, 36 and 41 into capital-intensive industries. And the remaining industries are tech-intensive industries. Then we operate the coefficient estimation and results are reported in Column (1)-(3) of Table 7. It is manifest that human capital expansion has significantly negative effects on both labor-intensive and tech-intensive firms, and has insignificant effects on capital-intensive firms. What's more, the effect of human capital expansion on the domestic value-added rate is more prominent for tech-intensive firms. The possible explanation is that armed with state-of-the-art facilities and equipment, tech-intensive firms are more likely to attract a multitude of superb talents. Therefore, human capital expansion has a more prominent effect on the domestic value-added rate for tech-intensive firms.

Furthermore, we explore the differential responses of human capital expansion on low-tech firms and high-tech firms. To be specific, we respectively operate the coefficient estimation of human capital expansion on the domestic value-added rate from low-tech firms and high-tech firms. Estimation results are displayed in Column (4)-(5) of Table 7, showing that human capital expansion has a significantly negative impact on the domestic value-added rate for high-tech firms. And the effect for low-tech firms is insignificant. An alternative explanation might be that for many technological firms, they are more likely to attract a great many able and outstanding talents and have the chance to translate human capital's talents into concrete benefits, therefore they are sensitive to human capital expansion to a larger extent.

7.3. Heterogeneous effects by academic field

Referring existing literatures, we investigate heterogeneous responses of human capital expansion on the domestic value-added rate of firms' exports by different disciplines. To be specific, we explore disciplines of science and engineering and disciplines of economics, management and law. Column (1)-(4) of Table 8 present the empirical estimation results based on different academic fields. It is manifest that the impact of human capital expansion on the domestic value-added rate of exports correlates to the academic

Table 7
Heterogeneous effects by factor intensity and technical complexity.

Dependent: DVAR	Factor Intensity			Technical Complexity	
	(1) Labor-intensive	(2) Capital-intensive	(3) Tech-intensive	(4) Low-tech	(5) High-tech
$HC_j \times POST02_t$	-0.3552***	0.0440	-0.3684***	-0.0903	-0.2172***
	(0.0900)	(0.1091)	(0.0812)	(0.0700)	(0.0493)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes
R^2	0.7395	0.7683	0.7664	0.7388	0.7759
Obs	129,594	76,664	83,188	148,293	140,873

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

Table 8
Heterogeneous effects by academic field.

Dependent: DVAR	(1) Science and engineering	(2) Economics, management, and law	(3) Other fields	(4) All
$HC_j \times POST02_t$	-0.0403	-0.3422***	-0.1433***	-0.1961**
	(0.1038)	(0.0547)	(0.0543)	(0.0974)
$HC_j \times POST02_t \times scienceshare$	-0.3580*			-0.2993
	(0.1888)			(0.1838)
$HC_j \times POST02_t \times emlawshare$		0.5070***		0.4857***
		(0.1188)		(0.1140)
$HC_j \times POST02_t \times other$			-0.2440**	
			(0.1076)	
Firm-level controls	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
R^2	0.7640	0.7640	0.7640	0.7641
Obs	127,199	127,199	127,199	127,199

Note: The robust standard errors are in parentheses, which are clustered at the firm level. *, **, *** denote significance at the 10%, 5%, and 1% levels.

fields. Notably, for disciplines of economics, management and law, human capital expansion promotes the domestic value-added rate of exports. As for disciplines of science and engineering and other disciplines, human capital expansion has negative effects on the domestic value-added rate in exports.

Specifically, Column (1) of Table 8 demonstrates that the coefficient of the triple interaction term for science and engineering field is significantly negative, implying that in regions where most college and university graduates engage in science and engineering field, human capital expansion has a significantly negative effect on the domestic value-added rate of exports. As shown in Table 8 Column (2), the coefficient of triple difference term for disciplines of economics, management and law is significantly positive. The result indicates that human capital expansion in this field has promoted the domestic value-added rate of exports. In Table 8 Column (3), the estimation result shows that human capital expansion has negative effects on the domestic value-added rate of exports to a greater extent for other disciplines. And the results of the Table 8 Column (4) further corroborate that the effect of human capital expansion on the domestic value-added rate of exports indeed correlates to the academic field.

8. Conclusion

The world economy has entered the era of global value chain, in which products are jointly completed by many countries in the global scale. This paper firstly constructs a nested CES production function model, with import inputs being complementary to skilled labors, and substitutable to unskilled labors. By exploiting China's higher education expansion as a quasi-natural experiment, this paper accurately examines the causal effect of the human capital expansion on the domestic value-added in exports. The results show that human capital expansion has negative effects on the domestic value-added in exports, and this result is driven by processing trade engagement and import inputs increase. We also find that the effect is more prominent for processing trade, foreign-invested firms, high-tech firms and disciplines of science and engineering. Actually, the rapid growth of China' export can attribute to its specific characteristics. To be specific, China's processing trade accounts for a large part of the gross trade, the basic pattern of which is conducting simple processing tasks with import inputs. As checked by our mechanism analysis, human capital expansion promotes the ratio of the processing trade to increase, which thus expand import inputs and further leads to lower level of the domestic value-added rate of firms' exports. Due to these kinds of China-specific characteristics, the conclusion of our paper is China-specific.

The findings of this paper also have profound policy significance. The results of this paper indicate that, human capital expansion has negative influence on the domestic value-added rate of firms' exports. This result provides strong empirical support for the policy

effect of China's Higher Education Enrollment from the global value chain. In addition, the fact that human capital can largely promote import inputs and encourage firms to engage in processing trade is of great significance to the new pattern of opening up. For some developing countries such as Vietnam, the conclusion of this paper can also provide lessons. On the one hand, it is recommended to shift this kind of trade pattern and to realize trade transformation and upgrading, since processing trade-based pattern can lead economies to be locked into the lower end of the global value chain. On the other hand, to increase trade gains, economies should achieve a higher level of human capital and realize innovation-driven development. And it's also advisable to develop vocational education and adult education while perusing higher education enrollment.

Funding

This paper was supported by the National Natural Science Foundation of China [Grant No. 72003151; 72173100], the Soft Science Research Program of Sichuan Province [Grant No. 2022JDR0227; 2021JDR0133], the China Postdoctoral Science Foundation [Grant No. 2022M721897], the Fundamental Research Funds for the Central Universities [Grant No. JBK230115; JBK2304148].

Declaration of Competing Interest

We, as the authors for the manuscript titled Higher education expansion and domestic value added in exports: Theory and evidence from China, declare no conflict of interest.

References

Acemoglu, D. (1996). A microfoundation for social increasing returns in human capital accumulation. *The Quarterly Journal of Economics, 111*(3), 779–804.
Acemoglu, D. (1998). Why do new technologies complement skills? directed technical change and wage inequality. *The Quarterly Journal of Economics, 113*(4), 1055–1089.
Ahn, J. B., Khandelwal, A. K., & Wei, S. J. (2011). The role of intermediaries in facilitating trade. *Journal of International Economics, 84*(1), 73–85.
Aichele, R., & Heiland, I. (2018). Where is the value added? Trade liberalization and production networks. *Journal of International Economics, 115*, 130–144.
Angrist, J. D., & Pischke, J. S. (2008). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton: Princeton University Press,.
Atkin, D. (2016). Endogenous skill acquisition and export manufacturing in Mexico. *American Economic Review, 106*(8), 2046–2085.
Bas, M., & Strauss-Kahn, V. (2015). Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics, 95*(2), 250–262.
Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates. *The Quarterly Journal of Economics, 119*(1), 249–275.
Brandt, L., Van Biesebroeck, J., & Zhang, Y. (2012). Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing. *Journal of Development Economics, 97*(2), 339–351.
Che, Y., & Zhang, L. (2017). Human capital, technology adoption and firm performance: impacts of China's higher education expansion in the late 1990s. *Economic Journal, 127*(4), 75–105.
Che, Y., Zhang, L., & Zhang, Y. (2018). Skilled labor and successful exporters: evidence from China. Working Paper.
Ciccone, A., & Papaioannou, E. (2009). Human capital, the structure of production and growth. *Review of Economics and Statistics, 91*(1), 66–82.
Dai, F., Cai, F., & Zhu, Y. (2021). Returns to higher education in China - evidence from the 1999 higher education expansion using fuzzy regression discontinuity. *Applied Economics Letters, 29*(6), 489–494.
Dean, J. M., Fung, K. C., & Wang, Z. (2011). Measuring vertical specialization: the case of China. *Review of International Economics, 19*(4), 609–625.
Fan, J. (2019). Internal geography, labor mobility, and the distributional impacts of trade. *American Economic Journal: Macroeconomics, 11*(3), 252–288.
Fu, H., Ge, R., Huang, J., & Shi, X. (2022). The effect of education on health and health behaviors: Evidence from the college enrollment expansion in China. *China Economic Review, 72*, Article 101768.
Huang, B., Tani, M., Wei, Y., & Zhu, Y. (2022). Returns to education in China: Evidence from the great higher education expansion. *China Economic Review*, Article 101804.
Hummels, David, Ishii, Jun, & Yi, Kei-mu (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics, 54*, 75–96.
Hummels, D., & Klenow, P. J. (2005). The variety and quality of a nation's exports. *American Economic Review, 95*(3), 704–723.
Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: production sharing and trade in value added. *Journal of International Economics, 86*(2), 224–236.
Kasahara, H., & Lapham, B. (2013). Productivity and the decision to import and export: theory and evidence. *Journal of International Economics, 89*(2), 297–316.
Kee, H. L., & Tang, H. (2016). Domestic value added in exports: theory and firm evidence from China. *American Economic Review, 106*(6), 1402–1436.
Knight, J., Deng, Q., & Li, S. (2017). China's expansion of higher education: The labour market consequences of a supply shock. *China Economic Review, 43*, 127–141.
Koopman, R., Wang, Z., & Wei, S. J. (2012). Estimating domestic content in exports when processing trade is pervasive. *Journal of Develpment Economics, 99*(1), 178–189.
Lafortune, J., Lewis, E., & Tessada, J. (2019). People and machines: a look at the evolving relationship between capital and skill in manufacturing, 1860–1930, using immigration shocks. *Review of Economics and Statistics, 101*(1), 30–43.
Lewis, E. (2011). Immigration, skill mix, and capital skill complementarity. *Quarterly Journal of Economics, 126*(2), 1029–1069.
Li, B. (2018). Export expansion, skill acquisition and industry specialization: evidence from China. *Journal of International Economics, 114*, 346–361.
Li, H., Ma, Y., Meng, L., Qiao, X., & Shi, X. (2017). Skill complementarities and returns to higher education: Evidence from college enrollment expansion in China. *China Economic Review, 46*, 10–26.
Liu, Q., & Qiu, L. (2016). Intermediate input imports and innovations: evidence from Chinese firms' patent filings. *Journal of International Economics, 103*, 166–183.
Lu, M., & Zhang, X. (2019). Towards an intelligent country: China's higher education expansion and rural children's senior high school participation. *Economic Systems, 43*(2), Article 100694.
Lu, Y., Deng, L., & Zeng, K. (2022). Foreign direct investment, innovation, and domestic value-added in exports: Firm-level evidence from China. *Review of International Economics, 30*(4), 1199–1228.
Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*(1), 3–42.
Ludema, R. D., Mayda, A. M., Yu, Z., & Yu, M. (2021). The political economy of protection in GVCs: Evidence from Chinese micro data. *Journal of International Economics, 131*, Article 103479.
Nelson, R. R., & Phelps, E. S. (1966). Investment in humans, technological diffusion, and economic growth. *American Economic Review, 56*(1/2), 69–75.
Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy, 94*(5), 1002–1037.
Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5), 71–102.
Schott, P. K. (2004). Across-product versus within-product specialization in international trade. *The Quarterly Journal of Economics, 119*(2), 647–678.
Upward, R., Wang, Z., & Zheng, J. (2013). Weighing China's export basket: the domestic content and technology intensity of Chinese exports. *Journal of Comparative Economics, 41*(2), 527–543.

Vogel, A., & Wagner, J. (2010). Higher productivity in importing German manufacturing firms: self-selection, learning from importing, or both? *Review of World Economics, 145*(4), 641–665.
Vrh, N. (2019). The DNA of the domestic value added (DVA) in exports: Firm-level analysis of DVA in exports. *The World Economy, 42*(9), 2566–2601.
Wang, Z., Wei, S. J., & Zhu, K. (2013). *Quantifying International Production Sharing at the Bilateral and Sector Levels (No. w19677)*. National Bureau of Economic Research,.
Wu, L., Chen, G., & Peng, S. (2021). Human capital expansion and global value chain upgrading: firm-level evidence from China. *China & World Economy, 29*(5), 28–56.
Xu, C. (2011). The fundamental institutions of China's reforms and development. *Journal of Economic Literature, 49*(4), 1076–1151.
Xiong, W., Yang, J., & Shen, W. (2022). Higher education reform in China: A comprehensive review of policymaking, implementation, and outcomes since 1978. *China Economic Review*, Article 101752.
Zhou, M., Li, Y. L., Yao, X., & Lu, Y. (2019). Human capital accumulation and urban manufacturing export upgrading in China: evidence from higher education expansion. *Management World, 35*(5), 64–77. +198-199.