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# Global Value Chain Participation and Productivity\*

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This study analyses the impact of firm-level participation in global value chains (GVCs) on productivity and production performance in Chinese manufacturing. Using a merged panel from the Annual Survey of Industrial Firms (ASIF) and Chinese Customs Trade Statistics (CCTS) for 1998–2007, we construct a binary indicator for GVC participation (two-way trading status) and continuous measures that capture backward and forward integration. To address selection and dynamic treatment concerns, we use firm fixed-effects estimations combined with a propensity-score-matching difference-in-differences (PSM-DID) framework with staggered treatment timing. We report three main findings. First, GVC participation is strongly associated with firm expansion; two-way traders have significantly higher output, employment, and domestic value added. Second, productivity effects vary. Forward participation, which measures domestic value added in foreign exports, is positively and consistently associated with total factor productivity (TFP), while backward participation, which indicates reliance on imported intermediates, is negatively associated with TFP and domestic value added. Third, productivity gains occur mainly at higher participation intensities, suggesting that deeper and more upstream integration is required for measurable efficiency improvements. Overall, the evidence indicates that the productivity effects of GVC integration depend on both the direction and depth of participation.

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*JEL classification:* F14, F15, D24

## Introduction

Over the past three decades, global value chains (GVCs) have significantly changed the organisation of international production. Instead of exporting final goods produced within national borders, firms now often engage in fragmented production processes, with specific tasks distributed across multiple countries. This shift, referred to as the ‘second unbundling’ (Baldwin, 2006; Antràs, 2020), has changed trade patterns, industrial specialisation, and firm strategies. A key question is whether participation in GVCs increases firm productivity and, if so, through which mechanisms.

Several theoretical channels indicate potential productivity gains. Importing intermediate inputs can improve input quality and variety, reduce costs, and support technology diffusion. Supplying intermediate goods to foreign markets may expose firms to stricter quality standards, learning opportunities, and knowledge spillovers from downstream buyers. However, these channels function differently depending on a firm’s structural position within the value chain. Downstream, import-intensive integration (backward participation) may increase export volumes without necessarily raising domestic value added. Upstream positioning (forward participation) may instead support upgrading and capability accumulation.

Empirical evidence is mixed, especially at the firm level and for emerging economies. China is an important case because, after its accession to the WTO in 2001, it became a central hub in global production networks. However, despite its significant role, there is limited micro-level evidence on how different forms of GVC participation affect the productivity of Chinese firms.

This study contributes to the existing literature in three ways. First, we present large-scale firm-level evidence from Chinese manufacturing during 1998–2007, using detailed production data and transaction-level customs records. Second, we decompose GVC participation into forward and backward components, and show that the direction of integration has sharply asymmetric productivity implications. Third, we improve causal interpretation by applying firm fixed effects together with a staggered-adoption propensity-score-matching difference-in-differences (PSM-DID) design. The additional ownership analysis further shows that the productivity consequences of GVC participation are not only direction-specific, but also shaped by firms’ ownership structure.

Our results show that although GVC participation consistently promotes firm expansion, productivity gains are sharply heterogeneous and are concentrated in forward-oriented and sufficiently intensive forms of integration, whereas import-intensive participation is not associated with comparable upgrading outcomes.

This paper focuses on Chinese manufacturing firms during 1998–2007, a period in which China was rapidly deepening its integration into global production networks following major trade liberalisation. While this historical setting is particularly informative for identifying firm-level patterns of GVC participation and productivity, it differs in important ways from the post-2008 and post-pandemic global environment. Accordingly, the paper should be read as providing evidence on the mechanisms linking GVC participation and firm performance in that period, rather than as a direct description of the current configuration of GVCs.

Before turning to the firm-level analysis, we provide brief industry-level background evidence using OECD ICIO data for four countries. This section is intended to motivate the broader link between GVC participation and productivity, while the main contribution of the paper comes from the firm-level Chinese analysis based on the Annual Survey of Industrial Firms (ASIF) and the Chinese Customs Trade Statistics (CCTS).

## GVC Participation and Industrial Productivity

This section provides broad industry-level background evidence on the relationship between GVC participation and productivity in a comparative setting. Its purpose is not to identify firm-level causal effects, but to motivate the subsequent micro-level analysis for China.

Much of the literature has addressed the impact of GVC participation on industrial productivity. Participation in GVCs is expected to increase productivity by improving efficiency through the international division of labour, expanding markets, and enabling a shift to higher-value-added processes.

Industries participate in GVCs in two main ways: through forward participation, in which a country supplies domestically produced intermediate goods to other countries' production processes, and through backward participation, in which a country receives intermediate goods produced by other countries for its own production processes.

The GVC participation index provides a quantitative measure of a country's or industry's involvement in GVCs. *Hummels et al.* (2001) define 'GVC Forward Participation' for country  $i$  and industry  $h$  in year  $t$  as the ratio of the value added created by that industry ( $IV_{i,h,t}$ ) and used as intermediate inputs in the production

of other countries' exported goods and services to the total exports of that industry ( $Exp_{i,t}$ ).

'GVC Backward Participation' refers to the share of value added generated in other countries ( $FVi_{i,h,t}$ ) that is used as intermediate inputs for the production of an industry's exported goods and services, measured relative to the industry's total exports. The definitions of Forward Participation ( $p_{i,h,t}^{\text{Forward}}$ ) and Backward Participation ( $p_{i,h,t}^{\text{Backward}}$ ) are as follows:

$$p_{i,h,t}^{\text{Forward}} = \frac{IV_{i,h,t}}{Exp_{i,t}},$$

$$p_{i,h,t}^{\text{Backward}} = \frac{FV_{i,h,t}}{Exp_{i,t}}.$$

Furthermore, the sum of forward participation and backward participation defines the GVC total participation index, as shown in the following equation:

$$p_{i,h,t}^{\text{Total}} = p_{i,h,t}^{\text{Forward}} + p_{i,h,t}^{\text{Backward}}.$$

The equation above shows that total participation increases when a greater share of value added from other countries is included in a country or industry's total exports, and when a larger share of the country's own value added is used in other countries' exports.

We estimate the following equation to analyse the relationship between the GVC participation index and industrial productivity:

$$y_{i,h,t} = \alpha + \beta GVC_{i,h,t-1} + \lambda_h + \lambda_{i,t} + \mu_{i,h,t}.$$

Here, the dependent variable  $y_{i,h,t}$  is the TFP growth rate (%) for country  $i$ , industry  $h$  in year  $t$  ( $TFP\ Growth_{i,h,t}$ ). On the right-hand side,  $\alpha$  is the constant term, and the explanatory variable  $GVC_{i,h,t-1}$  reflects the degree of GVC participation of the country  $i$  and industry  $h$ .  $\beta$  is expected to be positive and significant. These explanatory variables are lagged by one year to reduce potential reverse causality from GVC participation.  $\lambda_h$  and  $\lambda_{i,t}$  are fixed effects to control for unobservable factors: specifically,  $\lambda_h$  is an industry-level fixed effect to control for industry characteristics that are constant over time. Additionally,  $\lambda_{i,t}$  are country-year level fixed effects, controlling for annual variation factors common to the country where the industry is located, such as economic shocks and business cycle trends. Finally,  $\mu_{i,h,t}$  is the error terms that is assumed to be independently and identically distributed (i.i.d.).

Calculating GVC participation requires international input–output tables, which comprehensively capture production and demand linkages across industries by identifying international flows of goods and services. This analysis uses the 2018

edition of the OECD/WTO Inter-Country Input–Output (ICIO) Tables, which provide input and output data for 67 countries and 36 industries for 2005–2015.<sup>a</sup> Four representative countries are selected for this study: the United States, Germany, Japan, and China.

TFP growth rates by industry in the United States and Germany are available from the 2023 edition of EU KLEMS (Bontadini *et al.*, 2023).<sup>b</sup> Data for Japan are provided by the Research Institute of Economy, Trade and Industry (RIETI) through the Japan Industrial Productivity Database 2023.<sup>c</sup> China's data are available from the China Industrial Productivity Database 2023, also provided by RIETI.<sup>d</sup> By linking these databases with the ICIO Tables, information on GVC participation and production performance for the United States, Germany, Japan, and China from 2005 to 2015 is accessible.

Table 1 shows the results of regressions using each industry's TFP growth rate as the dependent variable and variables related to GVC participation as explanatory variables. Models 1, 2, and 3 include overall GVC participation, forward GVC participation, and backward GVC participation, respectively. The results from Model 1 indicate that industries with higher total GVC participation have statistically significantly higher TFP growth rates. Specifically, a 1% increase in overall GVC participation increases the TFP growth rate by 0.007%. This result is consistent with Models 2 and 3, where both forward and backward GVC participation are positively and significantly associated with TFP growth rates.

<sup>a</sup>The 2018 OECD ICIO Table is accessible at the following URL: <https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm>.

<sup>b</sup>The EU KLEMS database provides international comparisons of output, inputs, and productivity at the industry level. The University of Groningen in the Netherlands primarily constructed the database, and LUISS University in Italy currently provides it. The 2023 edition includes data for European Union countries and the United States covering 1995–2020. Users can access the database at <https://euklems-intanprod-llee.luiss.it>. For detailed explanations of the data, see Bontadini *et al.* (2023).

<sup>c</sup>The Japan Industrial Productivity (JIP) Database 2023 is a data set produced under the 'East Asian Industrial Productivity' project within the 'Industrial and Corporate Productivity Improvement' programme at the Research Institute of Economy, Trade and Industry (RIETI). It provides information for analysing Japan's economic growth and industrial structural changes from 1994 to 2020, and is available at <https://www.rieti.go.jp/jp/database/JIP2023/index.html>.

<sup>d</sup>The China Industrial Productivity (CIP) Database 2023 is a data set developed in collaboration with Peking University Growth Lab and Hitotsubashi University Institute of Economic Research as part of RIETI's 'East Asian Industrial Productivity' project within the 'Industrial and Corporate Productivity Enhancement' programme. It provides information for analysing economic growth and changes in industrial structure in China from 1987 to 2017 and is available at <https://www.rieti.go.jp/jp/database/CIP2023/index.html>.

Table 1. GVC participation and industrial TFP growth rates.

|                        | (1)                    | (2)                   | (3)                  |
|------------------------|------------------------|-----------------------|----------------------|
| Total participation    | 0.00580**<br>(0.00278) |                       |                      |
| Forward participation  |                        | 0.00517*<br>(0.00283) |                      |
| Backward participation |                        |                       | 0.00231<br>(0.00171) |
| Industry FE            | Yes                    | Yes                   | Yes                  |
| Country-year FE        | Yes                    | Yes                   | Yes                  |
| Observations           | 1,232                  | 1,232                 | 1,210                |
| R-squared              | 0.058                  | 0.056                 | 0.061                |

*Notes:* The dependent variable is industry-level TFP growth. The key explanatory variable is alternatively total GVC participation, forward GVC participation, or backward GVC participation. All explanatory variables are lagged by one year. The specifications include industry fixed effects and country-year fixed effects. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## Literature Review

While GVCs are widely recognised in the literature as important technological channels (Pietrobelli and Rabellotti, 2010), this study examines how they also significantly transmit tangible productivity gains at both the sectoral and firm levels.

To account for GVC participation, the literature distinguishes the direction of trade integration (Hummels *et al.*, 2001) by analysing backward participation, defined as the amount of foreign input (foreign value added) contained in a sector's or firm's domestic exports, and forward participation, defined as the use of domestic intermediates (domestic value added) embodied in other countries' exports.

At the sectoral level, Yanikkaya and Altun (2020) show that sectors with higher GVC participation experience not only higher output but also increased total factor productivity (TFP) growth. However, these gains decline in the years following the 2008 crisis. At the firm level, Banh *et al.* (2020) analyse micro-level data and find that greater GVC participation by industries and firms can increase aggregate productivity and growth in Estonia. Frontier firms, large firms by sales, and exporting firms benefit most from GVC knowledge spillovers, resulting in a productivity gap between globalised leaders and domestic laggards.

Banga (2022) empirically demonstrates that GVC participation can increase TFP in India. The study finds that Indian firms benefit most from policies that support ICT development and skills development, particularly in labour-intensive GVCs.

We examine the case of Japanese firms using the study by [Urata and Baek \(2022\)](#), which analyses data from 10,000 firms over 1994–2018 and applies the PSM-DID method. The authors found that GVC participation has a positive, though relatively modest, effect on firm productivity. Their findings indicate that sustained and successful integration into GVCs depends on firms' accumulated experience, with learning by doing playing a significant role over the long term.

Beyond the size and efficiency effects of firms ([Banh et al., 2020](#)), the structural trade direction can significantly influence the intensity of productivity gains. [Stemberger and Zajc Kejžar \(2025\)](#) use a PSM-DID approach with data from Slovenian firms for 2013–2022 to examine 'variations in thresholds for GVC participation, distinguishing pre- and post-treatment periods.' Their results show that GVC participation, when primarily driven by forward linkages and involving regional European partners, is associated with higher firm productivity.

The reported literature offers substantial evidence of the positive effects of GVC participation on productivity, drawing on both sectoral and firm-level studies and examining various geographical areas. Although recent contributions present a key advantage, no empirical study has yet analysed micro-level data using Chinese firms.

This study addresses that gap by connecting the existing literature with empirical sources on China. We use firm-level manufacturing data from the ASIF conducted by the National Bureau of Statistics of China for 1998–2007. We also use transaction-level customs data from the CCTS, compiled by the General Administration of Customs of China, for 2000–2014.

## Empirical Strategy and Data

### Data

The firm-level manufacturing data are from the ASIF, conducted by the National Bureau of Statistics of China for 1998–2007. The survey includes all state-owned enterprises (SOEs) and non-SOEs with annual sales above CNY5 million. Although the number of firms sampled differs each year, every annual wave provides detailed information on surveyed firms, such as firm identifiers, geographic location, industry classification, ownership structure, and financial and operational variables from accounting statements. These variables include total sales, employment, average wages, intermediate inputs, material purchases, value added, fixed assets, inventories, and profits. The ASIF data set allows researchers to construct firm-level revenue-based productivity measures using production function estimation methods based on [Levinsohn and Petrin \(2003\)](#).

To examine firms' international trade activities, we use transaction-level customs data from the CCTS, compiled by the General Administration of Customs of China. The CCTS data set records all merchandise trade transactions processed by Chinese customs each month from 2000 to 2014. Each transaction contains firm identification (name, address, and ownership type), HS eight-digit product codes, export values and quantities, customs regimes, modes of transportation, customs ports, and countries of origin and destination. To reduce seasonality and irregularities in monthly trade flows, we aggregate the data to the annual level. Product codes are converted from HS eight-digit to HS six-digit classifications. Export values are reported on a free-on-board (FOB) basis and denominated in USD.

We harmonise firm identifiers across ASIF and CCTS using a composite key that includes firm name, registered address, and legal representative name. Next, we merge the two data sets at the firm-year level. We apply standard cleaning procedures for merged ASIF–customs panels: dropping observations with missing core variables, removing implausible values, and ensuring consistent firm identifiers over time so that firms can be tracked in a panel. The empirical analysis uses the cleaned panel, with sample sizes for each outcome determined by the availability of the relevant variables and the transformations required by log specifications.

### GVC participation measure

Building on the previous paragraphs, we define a 'GVC firm' as a two-way trader, meaning a firm that both imports and exports within a given year, following [Urata and Baek \(2022\)](#). This indicator offers a clear classification of firms engaged in fragmented international production. In addition to this binary classification, and consistent with [Stemberger and Zajc Kejžar \(2025\)](#), we construct continuous indices to distinguish backward and forward participation. Backward participation refers to the imported content relative to a firm's production scale, while forward participation captures the share of domestic value added included in intermediate exports. Formally, for firm  $i$  in year  $t$ , forward participation is defined as

$$\text{GVC Participation}_{i,t}^{\text{Forward}} = \frac{\text{Intermediate}_{i,t}^{\text{Export}} \left( \frac{\text{Value added}_{i,t}}{\text{Total sale}_{i,t}} \right)}{\text{Export}_{i,t}}$$

where  $\text{Intermediate}_{i,t}^{\text{Export}}$  and  $\text{Export}_{i,t}$  are firm-year exports aggregated from CCTS, and  $\text{Value added}_{i,t}$  is from ASIF. Intuitively,  $\frac{\text{Value added}_{i,t}}{\text{Total sale}_{i,t}}$  scales intermediate exports by the firm's domestic value-added share. On the other hand, backward

participation is defined as

$$\text{GVC Participation}_{i,t}^{\text{Backward}} = \frac{\text{Intermediate}_{i,t}^{\text{Import}} + \text{Consumer goods}_{i,t}^{\text{Import}}}{\text{Total sale}_{i,t}}$$

where  $\text{Intermediate}_{i,t}^{\text{Import}}$  and  $\text{Consumer goods}_{i,t}^{\text{Import}}$  are firm-year imports aggregated from CCTS, and  $\text{Total sale}_{i,t}$  is from ASIF. Finally, total participation is the sum of the two components:

$$\text{GVC Participation}_{i,t}^{\text{Total}} = \text{GVC Participation}_{i,t}^{\text{Backward}} + \text{GVC Participation}_{i,t}^{\text{Forward}}$$

By construction, the indices range from 0 to 1. The continuous participation measures are available for 1,910,102 firm-years. The summary statistics show that participation is distributed asymmetrically. The GVC dummy has a mean of 0.079, so about 7.9% of firm-year observations are classified as two-way traders. The continuous indices have low means (backward: 0.0029; forward: 0.0138; total: 0.0142), but their upper tails are significant (e.g. forward participation reaches up to 0.708), which makes interpreting percentage-point changes economically relevant (Table 2).

### Empirical strategy

This study estimates the effect of firm-level participation in GVCs on performance, distinguishing the roles of backward and forward linkages. The main econometric challenge is self-selection: firms participating in GVCs differ from non-

Table 2. Summary statistics.

| Variable               | Interpretation                     | Obs.      | Mean  | Min    | Max    |
|------------------------|------------------------------------|-----------|-------|--------|--------|
| ln Output              | (log of) Industrial output         | 1,680,096 | 9.973 | 6.829  | 15.166 |
| ln Size                | (log of) No. of employees          | 1,570,189 | 4.726 | 2.197  | 7.811  |
| ln VA                  | (log of) Value-added               | 1,473,526 | 8.671 | 0      | 25.817 |
| ln TFP                 | (log of) Total factor productivity | 1,400,037 | 1.064 | −5.979 | 7.430  |
| K/L ratio              | (log of) Capital–labour ratio      | 1,502,073 | 3.469 | −8.234 | 17.235 |
| GVC dummy              | Two-way trader dummy               | 1,910,102 | 0.079 | 0      | 1      |
| Forward participation  | GVC forward participation          | 1,910,102 | 0.014 | 0      | 0.708  |
| Backward participation | GVC backward participation         | 1,910,102 | 0.003 | 0      | 0.205  |
| Total participation    | GVC total participation            | 1,910,102 | 0.014 | 0      | 0.304  |

*Notes:* This table reports summary statistics for the main firm-level variables used in the empirical analysis. The GVC dummy equals one if a firm both imports and exports in a given year. Backward, forward, and total participation are continuous indices ranging from 0 to 1. Variable definitions are provided in the ‘GVC participation measure’ section. Sample sizes vary across variables depending on data availability.

participants in observable characteristics, such as capital intensity, and may also differ in unobserved factors, such as managerial ability or product quality, that are correlated with performance. Additionally, firms may choose when to enter GVCs in response to shocks that also influence outcomes. To address these issues, we use three complementary strategies: first, firm-year fixed-effects regressions to capture within-firm variation over time; and second, a PSM-DID design that compares treated firms to observationally similar never-treated firms and tracks outcome changes around the onset of treatment. The DID approach uses staggered adoption, as treatment timing varies across firms.

### Fixed-effect model

We estimate the following baseline specification:

$$y_{i,t} = \alpha + \beta \text{GVC indicator}_{i,t} + \gamma \mathbf{X}_{i,t} + \lambda_i + \lambda_t + \mu_{i,t}$$

where  $y_{i,t}$  reflects firm  $i$ 's production activity in year  $t$ . This includes firm output ( $\text{Output}_{i,t}$ ), value added ( $\text{VA}_{i,t}$ ), total factor productivity ( $\text{TFP}_{i,t}$ ), and employment ( $\text{Emp}_{i,t}$ ). The logarithmic values of these variables are used for the estimation. Because value added was not reported in the ASIF in 2004, it is calculated manually for that year as  $\text{VA}_{i,t} = \text{Intermediate}_{i,t} + \text{VA tax}_{i,t}$ .

$\text{TFP}_{i,t}$  is estimated using the Akerberg–Caves–Frazer (ACF) approach (Akerberg *et al.*, 2015). The ACF method estimates a production function and addresses input endogeneity identification issues that arise in proxy-variable approaches when firms choose labour flexibly. In practice, researchers estimate industry-specific production functions, such as those at the two-digit level, using intermediate inputs as proxies for unobserved productivity. They then recover firm-level productivity residuals as TFP.

The regressor  $\text{GVC indicator}_{i,t}$  is alternatively (a) a binary indicator for being a GVC firm (two-way trader), (b) backward participation, (c) forward participation, or (d) total participation. The control vector  $\mathbf{X}_{i,t}$  indicates the time-varying firm controls, including capital–labour ratio ( $K/L\text{ratio}_{i,t}$ ) and ownership dummies  $\text{SOE}_{i,t}$ ,  $\text{FOE}_{i,t}$ ,  $\text{HMT}_{i,t}$  for SOEs, foreign-owned enterprises (FOEs), and Hong Kong–Macao–Taiwan-invested firms (HMT). Capital intensity is a natural confounder in this context because more capital-intensive firms may be more likely to participate in cross-border production networks and may have different performance trajectories regardless of GVC participation. Accordingly,  $K/L\text{ratio}_{i,t}$  enters the fixed-effects regressions as a time-varying control and serves as the covariate in the propensity-score model used for matching.

Firm fixed effects  $\lambda_i$  absorb all time-invariant firm heterogeneity (persistent differences in technology, management, product scope, and location), while year

fixed effects  $\lambda_i$  absorb economy-wide shocks and policy changes common to all firms.  $\mu_{i,t}$  is the i.i.d. error term clustered at firm level. In the estimation sample underlying the regression tables, the number of firm-year observations varies across outcomes, owing to data availability:  $\text{Output}_{i,t}$  is observed for 1,680,096 firm-years;  $\text{EMP}_{i,t}$  for 1,570,189;  $\text{VA}_{i,t}$  for 1,473,526; and  $\text{TFP}_{i,t}$  for 1,400,037.

Identification relies on within-firm variation. For the binary GVC indicator,  $\beta$  measures the average within-firm difference in outcomes between periods of GVC participation as a two-way trader and periods of non-participation, conditional on controls and fixed effects. For the continuous participation indices,  $\beta$  captures semi-elasticities; it quantifies how outcomes change as participation intensity varies within the same firm over time. To examine whether these relationships differ systematically across ownership types, we also estimate augmented fixed-effects specifications that interact each GVC indicator with ownership dummies for SOEs, FOEs, and HMT. These interaction terms allow us to assess whether the scale and productivity consequences of GVC participation vary across firms with different governance structures and modes of international integration.

### *PSM-DID design*

While firm fixed effects account for time-invariant unobserved factors, time-varying selection may still bias fixed-effects estimates. Firms may increase GVC participation in anticipation of future expansion, or shocks to demand, finance, or technology may simultaneously influence participation and outcomes. To address this, we use a PSM-DID strategy that first matches treated and control firms on pre-treatment observables, and then estimates differential changes in outcomes before and after treatment onset.

Propensity scores are estimated using a logit model at the firm level:

$$\Pr(\text{Treatment}_{i,t} = 1) = \Phi(\alpha + \gamma \mathbf{X}_{i,t} + \lambda_i + \lambda_t).$$

We conduct nearest-neighbour matching with five neighbours ( $\text{NN} = 5$ ) using the estimated propensity score and impose common support. For treated firms, we measure the capital-labour ratio before treatment onset; for potential controls, we use a comparable pre-treatment period.

On the matched sample, we estimate DID regressions with firm and year fixed effects:

$$y_{i,t} = \alpha + \beta_1 \text{Treatment}_{i,t} + \beta_2 \text{Post}_{i,t} + \beta_3 \text{Treatment}_{i,t} * \text{Post}_{i,t} + \lambda_i + \lambda_t + \varepsilon_{i,t}$$

Treatment is defined using the total GVC participation index. For a given threshold  $\tau$ , firm  $i$  is classified as treated ( $\text{Treatment}_{i,t} = 1$ ) if its total participation exceeds  $\tau$  at least once during 2000–2007. The treatment year  $t_i^*$  is the first year in which

total participation crosses  $\tau$ . We then define  $\text{Post}_{i,t} = 1$  for all years  $t \geq t_i^*$  for treated firms, and  $\text{Post}_{i,t} = 0$  otherwise. The control group consists of never-treated firms whose total participation never exceeds  $\tau$  during the sample window. The coefficient  $\beta_3$  is the average treatment effect on the treated (ATT), identified from differential within-firm changes for treated firms relative to matched never-treated firms over the same calendar years. Standard errors are clustered at the firm level. As an additional robustness check motivated by the pre-treatment trend diagnostics, we also estimate two augmented matched-DID specifications. The first replaces common year effects with industry-year fixed effects based on firms' main pre-treatment output industry, thereby absorbing industry-specific shocks that may differentially affect treated and control firms over time. The second allows firms with different initial export exposure to follow different time paths by including initial export intensity interacted with year effects. These specifications are intended to assess whether the pre-treatment imbalance in the baseline output equation is driven by omitted sector-specific shocks or by differential pre-treatment export exposure rather than by the treatment itself.

Because the treatment year  $t_i^*$  differs across firms, DID estimators based on two-way fixed effects can be biased under heterogeneous treatment effects. To address this issue, we follow Callaway and Sant'Anna (2021) and frame identification in terms of group-time average treatment effects. Let  $G$  denote the cohort defined by the first treatment year ( $G = g$  if  $t_i^* = g$ ). For each cohort  $g$  and calendar year  $t$ , the group-time average treatment effect for cohort  $g$  at calendar time  $t$  is  $\text{ATT} = E[Y_t(1) - Y_t(0)|G = g]$ , where  $Y_t(1)$  is the potential outcome at time  $t$  under treatment, and  $Y_t(0)$  is the potential outcome at time  $t$  under no treatment. The Callaway–Sant'Anna approach then aggregates  $\text{ATT}(g, t)$  across cohorts and time to obtain an overall ATT and dynamic (event-time) effects.

## Results

This section presents evidence on the impact of GVC participation on the performance of Chinese manufacturing firms. We report two sets of estimates. First, we use firm–year fixed-effect regressions to relate within-firm changes in outcomes to changes in GVC status and participation intensity. Second, we apply a PSM-DID model. In this approach, treatment is defined by the year a firm's total GVC participation index first exceeds a specified threshold, while the control group consists of firms that are never treated during the sample period. This empirical structure follows the dual approach summarised in the presentation materials, which highlight fixed effects and PSM-DID as complementary strategies, define GVC participants as two-way traders, and construct both backward and forward participation measures. To improve readability, the revised paper

expands the notes below each empirical table so that variable definitions, treatment thresholds, fixed effects, matching procedures, and standard-error conventions can be understood independently of the main text.

### *Fixed-effect model*

We begin with a fixed-effect model in which the key regressor is a binary indicator for being a GVC firm, defined as a two-way trader that both imports and exports in a given year. Table 3 presents the results. The estimates show substantial and precisely measured performance differences. In column (1), the coefficient on the GVC indicator is 0.160, indicating that GVC firms have 16% higher output compared to years when the firm is not a two-way trader. Employment also rises; the coefficient in column (5) is 0.0897, which implies about 9% higher employment. Column (9) reports that value added increases by 0.147, or approximately 15% higher domestic value added. These results provide evidence of a robust ‘GVC premium’ in both scale and value creation, consistent with the view that GVC participation expands market access, increases the availability of imported inputs and varieties, and enables firms to operate at larger scale.

For productivity, the coefficient in column (13) for the GVC dummy is smaller in magnitude but remains statistically significant at 0.00452 at the 5% level. On average, being a two-way trader is associated with a modest increase in efficiency, as measured by ACF-based TFP. The small magnitude of this average effect indicates that the productivity outcomes of GVC integration likely vary across firms and may depend on the specific manner of participation, rather than solely on whether a firm engages in both imports and exports.

Decomposing GVC integration into forward and backward components reveals several notable patterns. Forward participation shows a consistently positive and economically significant association with all outcome variables, with especially large effects for value added and productivity. As shown in column (3), the estimated effect of forward participation on output is 0.0915, which is similar to the coefficient of 0.0910 in the employment regression. The effect is much larger for value added, with an estimated coefficient of 0.772, and the impact on TFP is estimated at 0.233. Because the participation indices range from zero to one, the estimated coefficients are best interpreted as percentage-point changes. A 1 percentage-point increase in forward participation is associated with approximately 0.09% higher output, 0.09% higher employment, 0.77% higher value added, and 0.23% higher TFP, conditional on firm fixed effects, year fixed effects, and the full set of control variables. The right-skewed distribution of forward participation in the data indicates that these effects represent economically meaningful differences across firms and over time. The larger impacts on value added and productivity

Table 3. Results from fixed-effect models.

| Dep. variable          | Output                |           |           | Employment |                        |           | Value-added |           |                       | TFP      |           |          |                        |           |           |           |
|------------------------|-----------------------|-----------|-----------|------------|------------------------|-----------|-------------|-----------|-----------------------|----------|-----------|----------|------------------------|-----------|-----------|-----------|
|                        | (1)                   | (2)       | (3)       | (4)        | (5)                    | (6)       | (7)         | (8)       | (9)                   | (10)     | (11)      | (12)     | (13)                   | (14)      | (15)      | (16)      |
| GVC dummy              | 0.160***<br>(0.00339) |           |           |            | 0.0897***<br>(0.00228) |           |             |           | 0.147***<br>(0.00572) |          |           |          | 0.00452**<br>(0.00191) |           |           |           |
| Forward participation  |                       | 0.0915*** |           |            |                        | 0.0910*** |             |           |                       | 0.772*** |           |          |                        | 0.233***  |           |           |
| Backward participation |                       | (0.0100)  | −1.469*** |            |                        | (0.00679) | −0.0125     |           |                       | (0.0167) | −1.526*** |          |                        | (0.00566) | −0.690*** |           |
| Total participation    |                       |           | (0.0403)  | 0.0571***  |                        |           | (0.0275)    | 0.146***  |                       |          | (0.0656)  | 0.564*** |                        |           | (0.0227)  | 0.0691*** |
| Control variables      | Y                     | Y         | Y         | Y          | Y                      | Y         | Y           | Y         | Y                     | Y        | Y         | Y        | Y                      | Y         | Y         | Y         |
| Firm FE                | Y                     | Y         | Y         | Y          | Y                      | Y         | Y           | Y         | Y                     | Y        | Y         | Y        | Y                      | Y         | Y         | Y         |
| Year FE                | Y                     | Y         | Y         | Y          | Y                      | Y         | Y           | Y         | Y                     | Y        | Y         | Y        | Y                      | Y         | Y         | Y         |
| Observations           | 1,155,874             | 1,155,874 | 1,155,874 | 1,155,874  | 1,220,752              | 1,220,752 | 1,220,752   | 1,220,752 | 876,515               | 876,515  | 876,515   | 876,515  | 1,128,831              | 1,128,831 | 1,128,831 | 1,128,831 |
| R-squared              | 0.904                 | 0.903     | 0.903     | 0.903      | 0.934                  | 0.934     | 0.934       | 0.934     | 0.837                 | 0.838    | 0.837     | 0.837    | 0.818                  | 0.819     | 0.819     | 0.818     |

Notes: The dependent variables are log output, log employment, log value added, and log TFP. The key explanatory variable is alternatively the GVC dummy, backward participation, forward participation, or total participation. All specifications include firm fixed effects and year fixed effects. Time-varying controls include the capital-labour ratio and ownership dummies. Standard errors clustered at the firm level are reported in parentheses. The participation indices range from 0 to 1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

align with an ‘upgrading through forward linkages’ mechanism, in which supplying intermediate inputs to foreign markets leads firms to meet higher quality standards, adopt more advanced production processes, and learn from downstream foreign partners.

In contrast, backward participation is negatively associated with output, value added, and productivity, while its relationship with employment is weak and statistically insignificant. The estimated coefficients are  $-1.469$  for output,  $-1.526$  for value added, and  $-0.690$  for TFP, while the coefficient for employment is small and close to zero. In percentage-point terms, a 1 percentage-point increase in backward participation is associated with approximately 1.47% lower output, 1.53% lower value added, and 0.69% lower TFP. These magnitudes require cautious interpretation because backward participation is generally small in both levels and changes. This interpretation can be examined more directly using the customs-regime information available in the CCTS data.

To further investigate this mechanism, we exploit the customs-regime information in the CCTS data and construct firm-level measures of processing-trade exposure. Specifically, we define a processing-trade dummy equal to one if a firm is involved in either processing exports or processing imports, and we also construct a processing-trade share measured as processing trade over total trade. Using these measures, we examine whether the negative association between backward participation and productivity is specific to firms engaged in processing trade or whether it holds more broadly.

The additional evidence shows that the negative productivity association of backward participation is not confined to the processing-trade context. In subgroup regressions, backward participation remains negatively and significantly associated with productivity both among ordinary traders and among firms involved in processing trade. This indicates that the baseline result is not driven solely by processing traders. At the same time, the estimated coefficients are economically larger for firms engaged in processing trade, which is consistent with the view that backward integration through lower value-added assembly-type activities may intensify the adverse productivity implications of backward participation. Interaction-based specifications using the processing-trade dummy and the processing-trade share lead to the same overall conclusion: accounting for processing-trade exposure does not eliminate the negative coefficient on backward participation. Taken together, these results suggest that processing trade is an important part of the economic context in which the negative backward-participation effect arises, but it does not fully explain the baseline relationship. Appendix Table A.1 reports the corresponding subgroup and interaction-based mechanism tests using these firm-level processing-trade indicators.

Total GVC participation is positively associated with all outcomes. These estimates reflect the net effect of a strongly positive forward component combined with a negative backward component. The positive overall association, especially for value added and productivity, indicates that in this sample, gains linked to forward participation outweigh the adverse correlations associated with backward participation. This finding has an important policy implication: deeper GVC integration alone does not guarantee productivity gains unless it is accompanied by a shift towards upstream, forward-oriented positions that support learning and domestic value creation.

Ownership heterogeneity further clarifies these average patterns. Appendix Table A.2 augments the fixed-effects specification by interacting each GVC indicator with ownership dummies for SOEs, FOEs, and HMT firms. The estimates show that the gains from GVC participation are not evenly distributed across ownership groups. For the binary GVC indicator, the scale premium remains positive across ownership categories, but the TFP premium is significantly stronger for SOEs and FOEs than for the omitted private domestic firms, while it is essentially absent for HMT firms. This suggests that the average GVC premium masks important differences in firms' ability to convert participation into productivity improvements.

The heterogeneity is especially informative for the continuous participation measures. The adverse association between backward participation and firm performance is substantially weaker for SOEs, and the SOE interaction terms are positive and highly significant in the value-added and TFP regressions, indicating that the negative baseline relationship is not uniform across ownership types. By contrast, the interaction terms for HMT firms are negative for output, employment, and TFP, implying that the unfavourable correlation between backward participation and performance is strongest in this group. Forward participation displays the opposite pattern. The SOE interaction terms are positive and significant across all four outcomes, suggesting that SOEs benefit more broadly from forward linkages. For FOEs and HMT firms, however, the forward-participation interactions are negative for output and employment but generally positive for value added and TFP, indicating that upgrading gains in these groups are concentrated more on efficiency and domestic value creation than on scale expansion. The alternative forward and total participation measures yield a similar ranking across ownership categories, reinforcing the view that ownership structure shapes both the scale and productivity consequences of GVC integration.

### *PSM-DID design*

We next present PSM-DID estimates, where treatment is defined by the first year a firm's total participation exceeds a specified threshold, and never-treated firms

serve as the control group. In the matching stage, we estimate a logit propensity score using the pre-treatment capital–labour ratio and apply five-nearest-neighbour matching. In the DID stage, we estimate the ATT as the coefficient on  $\text{Treatment}_{i,t} * \text{Post}_{i,t}$  in a regression that includes firm and year fixed effects. We report results for the baseline treatment definition ('Treatment (dummy)') and for alternative threshold definitions of 5%, 10%, and 20%.

The results are reported in Table 4. Across all treatment definitions, the effects on output are large and precisely estimated. Under the baseline definition, the coefficient on  $\text{Treatment}_{i,t} * \text{Post}_{i,t}$  is 0.217, indicating that output increases by approximately 22% for treated firms relative to matched never-treated controls after they cross the participation threshold. The effects remain positive and highly significant under alternative definitions, with coefficients of 0.134 for Treatment (5%), 0.122 for Treatment (10%), and 0.113 for Treatment (20%). The consistency of these estimates across thresholds shows that the output increase associated with GVC integration does not depend on a specific cutoff choice.

Employment responses show a similarly robust pattern. Under the baseline treatment definition, the estimated coefficient is 0.148, indicating an increase in employment of about 15% following treatment. When alternative thresholds are used, the estimated effects remain stable at 0.0936, 0.0915, and 0.0905 for Treatment (5%), (10%), and (20%), respectively. The consistency of these estimates suggests that entry into GVC participation is systematically associated with an increase in firms' labour demand.

Results for value added support an upgrading interpretation. Under the baseline definition, the estimated effect is 0.197, indicating an increase of approximately 20% in value added after treatment. With alternative thresholds, the estimated coefficients are 0.171 for Treatment (5%), 0.201 for Treatment (10%), and 0.300 for Treatment (20%). The large effect at the 20% threshold, about 35% in percentage terms, indicates that deeper participation is associated with greater domestic value creation. This finding is consistent with the fixed-effects decomposition, which shows that while two-way trading is linked to higher value added, the largest gains appear at higher participation intensities.

Productivity responses depend on participation intensity. Under the baseline treatment definition, the estimated effect on log TFP is  $-0.00424$ , which is close to zero and statistically insignificant. When treatment is defined using higher thresholds, productivity effects are positive and economically meaningful, with coefficients of 0.00778 for Treatment (5%), 0.0121 for Treatment (10%), and 0.0319 for Treatment (20%). The last estimate indicates an increase in TFP of approximately 3.2% after treatment. These results show that sufficiently intensive GVC participation is associated with measurable efficiency gains, while

Table 4. Results from PSM-DID models.

| Dep. variable     | (1)                   | (2)                   | (3)                   | (4)                   | (5)                   | (6)                    | (7)                    | (8)                    | (9)                   | (10)                  | (11)                  | (12)                  | (13)                  | (14)                    | (15)                   | (16)                   |
|-------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-------------------------|------------------------|------------------------|
|                   | Output                |                       |                       | Employment            |                       |                        | Value-added            |                        |                       | TFP                   |                       |                       |                       |                         |                        |                        |
| Treatment (dummy) | 0.217***<br>(0.00658) |                       |                       |                       | 0.148***<br>(0.00475) |                        |                        |                        | 0.197***<br>(0.00959) |                       |                       |                       | -0.00424<br>(0.00328) |                         |                        |                        |
| Treatment (5%)    |                       | 0.134***<br>(0.00545) |                       |                       |                       | 0.0936***<br>(0.00373) |                        |                        |                       | 0.171***<br>(0.00854) |                       |                       |                       | 0.00778***<br>(0.00282) |                        |                        |
| Treatment (10%)   |                       |                       | 0.122***<br>(0.00566) |                       |                       |                        | 0.0915***<br>(0.00387) |                        |                       |                       | 0.201***<br>(0.00890) |                       |                       |                         | 0.0121***<br>(0.00292) |                        |
| Treatment (20%)   |                       |                       |                       | 0.113***<br>(0.00617) |                       |                        |                        | 0.0905***<br>(0.00417) |                       |                       |                       | 0.300***<br>(0.00958) |                       |                         |                        | 0.0319***<br>(0.00323) |
| Firm FE           | Y                     | Y                     | Y                     | Y                     | Y                     | Y                      | Y                      | Y                      | Y                     | Y                     | Y                     | Y                     | Y                     | Y                       | Y                      | Y                      |
| Year FE           | Y                     | Y                     | Y                     | Y                     | Y                     | Y                      | Y                      | Y                      | Y                     | Y                     | Y                     | Y                     | Y                     | Y                       | Y                      | Y                      |
| Observations      | 413,690               | 425,978               | 389,605               | 323,858               | 434,976               | 449,021                | 410,861                | 340,461                | 310,677               | 322,507               | 294,675               | 243,320               | 410,017               | 421,335                 | 385,540                | 320,629                |
| R-squared         | 0.912                 | 0.911                 | 0.911                 | 0.910                 | 0.915                 | 0.919                  | 0.919                  | 0.921                  | 0.851                 | 0.851                 | 0.852                 | 0.852                 | 0.796                 | 0.802                   | 0.801                  | 0.799                  |

Notes: The table reports ATT estimates from PSM-DID regressions. Treated firms are defined as firms whose total GVC participation first exceeds the indicated threshold during 2000–2007; the treatment year is the first year of threshold crossing. The control group consists of never-treated firms whose total participation never exceeds the threshold during the sample period. Matching is based on the pre-treatment log capital–labour ratio using logit propensity scores and five nearest neighbours under common support. All regressions include firm and year fixed effects. Standard errors clustered at the firm level are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

low-intensity or marginal entry mainly leads to scale expansion rather than productivity improvement.

Because the matching stage relies only on the log capital–labour ratio and uses five nearest neighbours based on the logit propensity score, it is important to assess post-matching comparability between treated and control firms. Balance diagnostics reported in Table 5 show nearly perfect balance across all treatment definitions: treated and control firms have identical mean log capital–labour ratios at the reported precision, mean bias is zero, and Rubin’s B and R statistics are well within conventional thresholds. These results indicate that the PSM procedure effectively removes observable differences in capital intensity between the two groups.

Pre-treatment trend diagnostics reported in Table 6 provide a more detailed assessment. The average pre-treatment lead is statistically insignificant across outcomes, which does not indicate a systematic pre-treatment imbalance on average. However, some individual lead coefficients are statistically significant in specific cases. For output, the coefficient for the year immediately before treatment is negative and significant, indicating different dynamics just before threshold crossing. Similar patterns are observed for value added and productivity in certain leads. These results emphasise the need for transparency when interpreting DID estimates in a journal context.

To address this concern more directly, Appendix Table A.3 reports industry-year fixed effects based on firms’ pre-treatment main output industry. Under this specification, the estimated treatment effects remain positive across all four outcomes. Although the output coefficients become smaller than in the baseline

Table 5. Balance test.

|           | (1)               | (2)     | (3)            | (4)     | (5)             | (6)     | (7)             | (8)     |
|-----------|-------------------|---------|----------------|---------|-----------------|---------|-----------------|---------|
|           | Treatment (dummy) |         | Treatment (5%) |         | Treatment (10%) |         | Treatment (20%) |         |
|           | Treat             | Control | Treat          | Control | Treat           | Control | Treat           | Control |
| Mean      | 3.953             | 3.953   | 3.942          | 3.942   | 3.971           | 3.971   | 4.003           | 4.003   |
| Mean bias |                   | 0.000   |                | 0.000   |                 | 0.000   |                 | 0.000   |
| p-value   |                   | 1.000   |                | 1.000   |                 | 1.000   |                 | 1.000   |
| Rubin’s B |                   | 0.000   |                | 1.000   |                 | 1.000   |                 | 1.000   |
| Rubin’s R |                   | 1.000   |                | 1.000   |                 | 1.000   |                 | 1.000   |

*Notes:* This table reports covariate balance diagnostics for the matched sample used in the PSM stage. Matching is based on the pre-treatment log capital–labour ratio using five-nearest-neighbour logit propensity-score matching under common support. Mean bias refers to the standardised difference in covariate means between treated and control firms. Rubin’s B and Rubin’s R are standard summary statistics for assessing balance after matching.

Table 6. Parallel trend test.

|                          | (1)       | (2)     | (3)        | (4)     | (5)         | (6)     | (7)       | (8)     |
|--------------------------|-----------|---------|------------|---------|-------------|---------|-----------|---------|
|                          | Output    |         | Employment |         | Value-added |         | TFP       |         |
| Years prior to treatment | Coeff.    | p-value | Coeff.     | p-value | Coeff.      | p-value | Coeff.    | p-value |
| −5                       | −0.034    | 0.465   | −0.007     | 0.814   | −4.654      | 0.003   | −0.068    | 0.070   |
| −4                       | 0.007     | 0.830   | −0.023     | 0.087   | 0.643       | 0.735   | 0.029     | 0.130   |
| −3                       | 0.010     | 0.770   | −0.007     | 0.428   | 0.112       | 0.000   | 0.002     | 0.852   |
| −2                       | 0.014     | 0.497   | 0.004      | 0.656   | 0.084       | 0.000   | −0.002    | 0.842   |
| −1                       | −0.073    | 0.000   | 0.008      | 0.219   | 0.053       | 0.006   | 0.008     | 0.275   |
| Pre-treatment ave.       | −0.016    | 0.247   | −0.005     | 0.460   | −0.753      | 0.171   | −0.006    | 0.426   |
| Observations             | 13,37,134 |         | 12,11,475  |         | 10,94,242   |         | 10,43,476 |         |

*Notes:* This table reports event-time coefficients from the dynamic DID specification used to assess pre-treatment and post-treatment patterns around the first year in which a firm crosses the relevant GVC participation threshold. Coefficients are reported relative to the omitted reference period. Standard errors are clustered at the firm level. Statistically significant lead coefficients should be interpreted as evidence of possible deviations from parallel pre-treatment trends.

specification, they remain positive and statistically significant under all treatment definitions. Employment effects also remain positive and significant throughout, while value added continues to increase after treatment, with especially large estimates at higher participation thresholds. Importantly, the TFP coefficients are now positive under all treatment definitions and statistically significant except at the 5% threshold. These results suggest that the main post-treatment patterns are not driven solely by omitted industry-specific shocks.

Appendix Table A.4 instead allows firms with different initial export exposure to follow different time paths by including initial export intensity interacted with year effects. The coefficient on the export-intensity trend term is negative and statistically significant in most specifications, indicating that pre-existing export exposure is indeed associated with differential outcome dynamics over time. However, even after conditioning on these export-related trends, the treatment coefficients remain positive and statistically significant for output, employment, and value added, and the TFP effects become positive and statistically significant under all treatment definitions. Taken together, these additional specifications indicate that the main PSM-DID findings are robust to conditioning on both sector-specific time shocks and differential pre-treatment export exposure.

Across both fixed-effects and PSM-DID approaches, three main conclusions remain robust. First, GVC participation is associated with a substantial increase in firm scale, as shown by strong growth in output and employment. Second, GVC participation increases domestic value creation, with especially large gains in value

added at higher-intensity thresholds. Third, productivity gains are not automatic and depend on the nature and intensity of participation. Forward participation is strongly associated with higher ACF-based TFP, while backward participation is negatively associated with productivity in the fixed-effects estimates. In the matched-DID results, productivity effects are weak under the baseline treatment definition but become positive and larger at higher participation thresholds. The additional robustness specifications that condition on industry-year fixed effects and initial export-intensity trends preserve this overall pattern. Accordingly, the DID evidence is best interpreted as complementary support for the broader finding that the productivity benefits of GVC integration are concentrated in more intensive and more forward-oriented forms of participation.

## Conclusion

This study examines how firm-level participation in GVCs is associated with production performance among Chinese manufacturing firms. Using a merged panel of the ASIF and transaction-level CCTS for 1998–2007, we construct both a binary indicator of GVC participation, defined by two-way trading status, and continuous measures of backward, forward, and total participation. We combine firm fixed-effects estimations with a PSM-DID design to address selection and dynamic treatment concerns. Taken together, the results provide new micro-level evidence on the relationship between GVC participation and firm performance during a historically important phase of China's integration into global production networks. The industry-level evidence presented earlier is consistent with the broader idea that GVC participation and productivity are positively related, but the firm-level results in this paper show that, within China, these gains depend crucially on the direction and intensity of participation.

Three main findings emerge. First, GVC participation is strongly associated with firm-scale expansion. Across specifications, becoming a two-way trader is linked to substantial increases in output, employment, and domestic value added. The PSM-DID results confirm that firms crossing participation thresholds experience persistent post-treatment gains in scale compared with matched never-treated firms. These findings support the view that GVC integration relaxes demand-side constraints, expands market access, and provides access to a wider range of intermediate inputs, enabling firms to operate at a larger scale.

Second, the productivity effects of GVC participation vary and depend on both the direction and intensity of integration. Forward participation, which measures the supply of domestically generated value added embodied in foreign exports, is positively and consistently associated with TFP. In contrast, backward

participation, reflecting reliance on imported intermediates, is negatively associated with value added and TFP after controlling for firm and year fixed effects. Additional mechanism tests using firm-level processing-trade indicators show that this negative association is not confined to processing traders, although it is economically stronger among firms involved in processing trade. This pattern suggests that the productivity consequences of backward participation depend not only on imported input use itself, but also on the form of integration and the extent to which firms are concentrated in lower value-added stages of production. This asymmetry also varies meaningfully by ownership type. The additional interaction estimates show that SOEs tend to capture broader gains from forward-oriented participation and are less exposed to the adverse correlations associated with backward participation. HMT firms, by contrast, exhibit the weakest productivity gains from simple GVC participation and the strongest negative association with backward linkages, while FOEs lie between these two cases, with forward participation more clearly linked to value added and TFP than to scale expansion.

Third, productivity gains do not occur automatically. The PSM-DID estimates show that low-intensity GVC entry primarily leads to scale effects, while statistically and economically significant TFP improvements emerge only at higher participation thresholds. This pattern suggests that firms need a sufficient level of integration to internalise knowledge spillovers, upgrade production processes, and transition to higher value-added activities. Thus, deeper and more forward-oriented integration seems necessary to convert globalisation into sustained efficiency gains. This interpretation is further supported by the additional matched-DID specifications that condition on industry-year shocks and initial export-intensity trends, which leave the main post-treatment pattern intact.

Taken together, these findings contribute to the existing literature in two ways. First, they are broadly consistent with earlier studies showing that integration into GVCs is associated with firm expansion and, under some conditions, productivity improvement. At the same time, our results show more clearly that these gains are not uniform across modes of participation. In particular, forward participation is positively associated with productivity and domestic value creation, whereas backward participation is negatively associated with value added and TFP. Second, the results indicate that productivity gains are concentrated in more intensive forms of participation, rather than arising automatically from entry into GVCs. These findings extend the literature by showing that the direction and depth of GVC integration are central to understanding which firms benefit from globalisation and through which channels.

From a policy perspective, the findings suggest that promoting GVC integration alone may be insufficient to achieve durable productivity upgrading. In the historical context examined here, policies that support forward linkages, domestic

capability building, technological upgrading, quality certification, and digitalisation appear more likely to generate sustained efficiency gains than simple participation in import-intensive production segments. These findings also speak to current debates on resilience, diversification, and the regional reconfiguration of production networks. In particular, they suggest that successful integration into changing GVCs depends not only on participation itself, but also on whether firms can strengthen domestic value creation and move towards more knowledge-intensive and upstream positions. These implications should therefore be interpreted as mechanism-based lessons from the Chinese experience during 1998–2007 rather than as direct claims about the current organisation of global production.

Several limitations point to directions for future research. First, although firm fixed effects and PSM-DID improve identification, unobserved time-varying shocks may still affect both participation and performance. Second, the sample ends in 2007, and China's role in GVCs has evolved substantially since then through the global financial crisis, the expansion of domestic demand, and more recent supply-chain restructuring. Third, although the additional interaction estimates reveal meaningful heterogeneity by ownership type, future research could examine whether similar differences arise across firm size, technology intensity, regions, and trade regimes, and whether the asymmetric effects of forward and backward participation persist in more recent periods.

Overall, the evidence shows that GVC participation has been an important driver of firm growth in China; however, productivity upgrading depends on the manner of participation. The direction, depth, and structural position within GVCs are crucial for determining whether globalisation leads to sustained efficiency improvements.

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Appendix A

Table A.1. Effects of GVC backward participation in processing trade.

| Dep. variable          | Output                |                       |                       | Employment            |                      |                       | Value-added           |                       |                      | TFP                   |                       |                       |
|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------|-----------------------|-----------------------|-----------------------|----------------------|-----------------------|-----------------------|-----------------------|
|                        | D = 0                 | D = 1                 | Interaction           | Share                 | D = 0                | D = 1                 | Interaction           | Share                 | D = 0                | D = 1                 | Interaction           | Share                 |
| Backward participation | -1.066***<br>(0.0552) | -2.821***<br>(0.0835) | -1.645***<br>(0.0451) | -2.949***<br>(0.0991) | 0.229***<br>(0.0375) | -0.165***<br>(0.0540) | 0.0233<br>(0.0308)    | -0.180***<br>(0.0618) | -2.882***<br>(0.194) | -0.651***<br>(0.0312) | -0.717***<br>(0.0255) | -1.329***<br>(0.0629) |
| GVC_B*                 |                       |                       | 0.621***<br>(0.0721)  |                       |                      |                       | -0.127***<br>(0.0493) |                       | 0.543***<br>(0.121)  |                       | 0.0943***<br>(0.0405) |                       |
| Processing dummy       |                       |                       |                       |                       |                      |                       |                       |                       |                      |                       |                       |                       |
| Processing share       |                       |                       |                       | -0.0381*<br>(0.0204)  |                      |                       |                       | -0.0123<br>(0.0125)   |                      |                       |                       | -0.00408<br>(0.0130)  |
| Control variables      | Y                     | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     |
| Firm FE                | Y                     | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     |
| Year FE                | Y                     | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     | Y                    | Y                     | Y                     | Y                     |
| Observations           | 1,092,039             | 45,306                | 1,155,874             | 28,219                | 1,154,802            | 47,812                | 1,220,752             | 29,258                | 876,515              | 1,065,120             | 1,128,831             | 28,195                |
| R-squared              | 0.903                 | 0.924                 | 0.903                 | 0.931                 | 0.933                | 0.952                 | 0.934                 | 0.956                 | 0.837                | 0.820                 | 0.819                 | 0.824                 |

Notes: Robust standard errors clustered at firm in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

Table A.2. Results from fixed-effect models by firms' ownership.

| Dep. variable          | Output                |                      |                       | Employment            |                         |                      | Value-added          |                       |                       |                     |                       | TFP                 |                        |                      |                       |      |
|------------------------|-----------------------|----------------------|-----------------------|-----------------------|-------------------------|----------------------|----------------------|-----------------------|-----------------------|---------------------|-----------------------|---------------------|------------------------|----------------------|-----------------------|------|
|                        | (1)                   | (2)                  | (3)                   | (4)                   | (5)                     | (6)                  | (7)                  | (8)                   | (9)                   | (10)                | (11)                  | (12)                | (13)                   | (14)                 | (15)                  | (16) |
| GVC dummy              | 0.159***<br>(0.00344) |                      |                       |                       | 0.0910***<br>(0.00231)  |                      |                      |                       | 0.146***<br>(0.00576) |                     |                       |                     | 0.00372*<br>(0.00193)  |                      |                       |      |
|                        | 0.0753***<br>(0.0232) |                      |                       |                       | 0.0126<br>(0.0159)      |                      |                      |                       | 0.0189<br>(0.0479)    |                     |                       |                     | 0.0394***<br>(0.0130)  |                      |                       |      |
|                        | 0.0415***<br>(0.0139) |                      |                       |                       | -0.00470<br>(0.00962)   |                      |                      |                       | 0.110***<br>(0.0331)  |                     |                       |                     | 0.0234***<br>(0.00781) |                      |                       |      |
|                        | -0.0210*<br>(0.0115)  |                      |                       |                       | -0.0400***<br>(0.00794) |                      |                      |                       | -0.00123<br>(0.0263)  |                     |                       |                     | -0.00366<br>(0.00645)  |                      |                       |      |
| Forward participation  |                       |                      |                       |                       |                         |                      |                      |                       |                       |                     |                       |                     |                        |                      |                       |      |
| GVC_F*SOE              |                       | 1.148***<br>(0.0771) |                       |                       |                         | 0.818***<br>(0.0519) |                      |                       |                       | 5.073***<br>(0.126) |                       |                     |                        | 1.555***<br>(0.0436) |                       |      |
| GVC_F*FOE              |                       | 2.557***<br>(0.560)  |                       |                       |                         | 0.755*<br>(0.385)    |                      |                       |                       | 3.767***<br>(1.178) |                       |                     |                        | 1.274***<br>(0.318)  |                       |      |
| GVC_F*HMT              |                       | -1.832***<br>(0.415) |                       |                       |                         | -1.706***<br>(0.287) |                      |                       |                       | 1.742*<br>(0.893)   |                       |                     |                        | 1.962***<br>(0.233)  |                       |      |
| Backward participation |                       | -1.105***<br>(0.415) |                       |                       |                         | -0.961***<br>(0.286) |                      |                       |                       | 3.558***<br>(0.894) |                       |                     |                        | 1.088***<br>(0.232)  |                       |      |
|                        |                       |                      | -1.473***<br>(0.0410) |                       |                         |                      | -0.00370<br>(0.0280) |                       |                       |                     | -1.536***<br>(0.0663) |                     |                        |                      | -0.693***<br>(0.0231) |      |
|                        |                       |                      | 0.838<br>(0.628)      |                       |                         |                      | -0.144<br>(0.427)    |                       |                       |                     | 4.854***<br>(1.623)   |                     |                        |                      | 1.045***<br>(0.359)   |      |
|                        |                       |                      | 0.360**<br>(0.161)    |                       |                         |                      | 0.0560<br>(0.111)    |                       |                       |                     | 0.424<br>(0.346)      |                     |                        |                      | 0.195***<br>(0.0902)  |      |
| GVC_B*HMT              |                       | -1.105***<br>(0.170) |                       |                       |                         | -0.327***<br>(0.117) |                      |                       |                       | -0.139<br>(0.372)   |                       |                     |                        | -0.192**<br>(0.0952) |                       |      |
| Total participation    |                       |                      |                       |                       |                         |                      |                      |                       |                       |                     |                       |                     |                        |                      |                       |      |
| GVC_T*SOE              |                       |                      |                       | -0.619***<br>(0.0290) |                         |                      |                      | 0.195***<br>(0.0198)  |                       |                     |                       | -0.0574<br>(0.0464) |                        |                      | -0.138***<br>(0.0164) |      |
| GVC_T*FOE              |                       |                      |                       | 2.012***<br>(0.354)   |                         |                      |                      | 0.323<br>(0.243)      |                       |                     |                       | 4.003***<br>(0.779) |                        |                      | 1.628***<br>(0.203)   |      |
| GVC_T*HMT              |                       |                      |                       | -0.0841<br>(0.118)    |                         |                      |                      | -0.130<br>(0.0815)    |                       |                     |                       | -0.0576<br>(0.248)  |                        |                      | 0.198***<br>(0.0663)  |      |
|                        |                       |                      |                       | -0.549***<br>(0.134)  |                         |                      |                      | -0.405***<br>(0.0928) |                       |                     |                       | 0.00247<br>(0.295)  |                        |                      | -0.107<br>(0.0752)    |      |

Table A.2. (Continued)

| Dep. variable     | (1)       | (2)       | (3)       | (4)       | (5)        | (6)       | (7)       | (8)       | (9)         | (10)    | (11)    | (12)    | (13)      | (14)      | (15)      | (16)      |
|-------------------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-------------|---------|---------|---------|-----------|-----------|-----------|-----------|
|                   | Output    |           |           |           | Employment |           |           |           | Value-added |         |         |         | TFP       |           |           |           |
| Control variables | Y         | Y         | Y         | Y         | Y          | Y         | Y         | Y         | Y           | Y       | Y       | Y       | Y         | Y         | Y         | Y         |
| Firm FE           | Y         | Y         | Y         | Y         | Y          | Y         | Y         | Y         | Y           | Y       | Y       | Y       | Y         | Y         | Y         | Y         |
| Year FE           | Y         | Y         | Y         | Y         | Y          | Y         | Y         | Y         | Y           | Y       | Y       | Y       | Y         | Y         | Y         | Y         |
| Observations      | 1,155,874 | 1,155,874 | 1,155,874 | 1,155,874 | 1,220,752  | 1,220,752 | 1,220,752 | 1,220,752 | 876,515     | 876,515 | 876,515 | 876,515 | 1,128,831 | 1,128,831 | 1,128,831 | 1,128,831 |
| R-squared         | 0.904     | 0.903     | 0.903     | 0.903     | 0.934      | 0.934     | 0.934     | 0.934     | 0.837       | 0.837   | 0.837   | 0.837   | 0.818     | 0.819     | 0.819     | 0.818     |

Notes: Robust standard errors clustered at firm in parentheses. \*\*\*,  $p < 0.01$ , \*\*,  $p < 0.05$ , \*  $p < 0.1$ .

Table A.3. Robustness of PSM-DID estimates: industry-year fixed effects.

| Dep. variable     | (1)                    | (2)                    | (3)                    | (4)                    | (5)                 | (6)                | (7)                 | (8)                  | (9)                    | (10)                 | (11)                | (12)                | (13)                | (14)               | (15)                 | (16)                 |
|-------------------|------------------------|------------------------|------------------------|------------------------|---------------------|--------------------|---------------------|----------------------|------------------------|----------------------|---------------------|---------------------|---------------------|--------------------|----------------------|----------------------|
|                   |                        |                        | Output                 |                        |                     |                    | Employment          |                      |                        | Value-added          |                     |                     |                     |                    | TFP                  |                      |
| Treatment (dummy) | 0.0582***<br>(0.00429) |                        |                        |                        | 0.159**<br>(0.0703) |                    |                     |                      | 0.0424***<br>(0.00141) |                      |                     |                     | 0.106**<br>(0.0489) |                    |                      |                      |
| Treatment (5%)    |                        | 0.0332***<br>(0.00323) |                        |                        |                     | 0.140*<br>(0.0770) |                     |                      |                        | 0.235***<br>(0.0256) |                     |                     |                     | 0.0619<br>(0.0566) |                      |                      |
| Treatment (10%)   |                        |                        | 0.0191***<br>(0.00187) |                        |                     |                    | 0.154**<br>(0.0603) |                      |                        |                      | 0.279***<br>(0.691) |                     |                     |                    | 0.0873**<br>(0.0434) |                      |
| Treatment (20%)   |                        |                        |                        | 0.0197***<br>(0.00186) |                     |                    |                     | 0.151***<br>(0.0528) |                        |                      |                     | 0.563***<br>(0.146) |                     |                    |                      | 0.101***<br>(0.0372) |
| Firm FE           | Y                      | Y                      | Y                      | Y                      | Y                   | Y                  | Y                   | Y                    | Y                      | Y                    | Y                   | Y                   | Y                   | Y                  | Y                    | Y                    |
| Industry-Year FE  | Y                      | Y                      | Y                      | Y                      | Y                   | Y                  | Y                   | Y                    | Y                      | Y                    | Y                   | Y                   | Y                   | Y                  | Y                    | Y                    |
| Observations      | 413,690                | 425,978                | 389,605                | 323,858                | 434,976             | 449,021            | 410,861             | 340,461              | 310,677                | 322,507              | 294,675             | 243,320             | 410,017             | 421,335            | 385,540              | 320,629              |
| R-squared         | 0.687                  | 0.592                  | 0.728                  | 0.823                  | 0.974               | 0.979              | 0.976               | 0.983                | 0.944                  | 0.951                | 0.975               | 0.990               | 0.979               | 0.979              | 0.977                | 0.984                |

Notes: Robust standard errors clustered at firm in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

Table A.4. Robustness of PSM-DID estimates: initial export-intensity trends.

| Dep. variable         | (1)                   | (2)                   | (3)                    | (4)                    | (5)                   | (6)                    | (7)                   | (8)                   | (9)                  | (10)                 | (11)                 | (12)                 | (13)                  | (14)                   | (15)                   | (16)                   |
|-----------------------|-----------------------|-----------------------|------------------------|------------------------|-----------------------|------------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|------------------------|------------------------|------------------------|
|                       | Output                |                       |                        | Employment             |                       |                        | Value-added           |                       |                      | TFP                  |                      |                      |                       |                        |                        |                        |
| Treatment (dummy)     | 0.229***<br>(0.00862) |                       |                        |                        | 0.122***<br>(0.00602) |                        |                       |                       | 0.232***<br>(0.0132) |                      |                      |                      | 0.0100**<br>(0.00428) |                        |                        |                        |
| Treatment (5%)        |                       | 0.120***<br>(0.00649) |                        |                        |                       | 0.0403***<br>(0.00627) |                       |                       |                      | 0.204***<br>(0.0132) |                      |                      |                       | 0.0495***<br>(0.00449) |                        |                        |
| Treatment (10%)       |                       |                       | 0.0981***<br>(0.00667) |                        |                       |                        | 0.0298***<br>(0.0104) |                       |                      |                      | 0.130***<br>(0.0214) |                      |                       |                        | 0.0448***<br>(0.00830) |                        |
| Treatment (20%)       |                       |                       |                        | 0.0858***<br>(0.00734) |                       |                        |                       | 0.0488***<br>(0.0239) |                      |                      |                      | 0.323***<br>(0.0116) |                       |                        |                        | 0.0532***<br>(0.00381) |
| Export intensity*Year | Y                     | Y                     | Y                      | Y                      | Y                     | Y                      | Y                     | Y                     | Y                    | Y                    | Y                    | Y                    | Y                     | Y                      | Y                      | Y                      |
| Firm FE               | Y                     | Y                     | Y                      | Y                      | Y                     | Y                      | Y                     | Y                     | Y                    | Y                    | Y                    | Y                    | Y                     | Y                      | Y                      | Y                      |
| Year FE               | Y                     | Y                     | Y                      | Y                      | Y                     | Y                      | Y                     | Y                     | Y                    | Y                    | Y                    | Y                    | Y                     | Y                      | Y                      | Y                      |
| Observations          | 132,036               | 149,478               | 133,387                | 106,271                | 137,347               | 96,860                 | 49,486                | 10,809                | 102,238              | 73,170               | 37,741               | 83,527               | 131,301               | 91,244                 | 46,758                 | 105,374                |
| R-squared             | 0.890                 | 0.889                 | 0.889                  | 0.887                  | 0.893                 | 0.895                  | 0.890                 | 0.885                 | 0.823                | 0.813                | 0.801                | 0.825                | 0.753                 | 0.760                  | 0.755                  | 0.767                  |

Notes: Robust standard errors clustered at firm in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

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