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Research Paper

Impact of global value chain on China's automobile industry upgrading: The mediating effect of technology investment and moderating effect of foreign direct investment

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Abstract

The automobile industry is a cornerstone of China's economy, with its upgrading significantly influencing overall economic growth. Global value chain (GVC), as a framework that connects global markets and production resources, substantially impacts an industry's international competitiveness. This study employs the Malmquist Productivity Index based on the Data Envelopment Analysis (DEA) method to assess China's automobile industry (CAI). Additionally, a system Generalized Method of Moments (GMM) approach is utilized to investigate the influence of GVC on the upgrading process while further examining the mediating and moderating roles of technological innovation and foreign direct investment (FDI). The findings show that GVC has a significant negative effect on upgrading CAI, with technology investment acting as a mediating factor; specifically, GVC hinders industry upgrading by inhibiting technology investment. Furthermore, FDI mitigates the negative impact of GVC on the upgrading of CAI. Based on these findings, this study offers policy implications to promote the upgrading of CAI.

Keywords: Global value chain, Industrial upgrading, FDI, Technological innovation，GMM.

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Introduction

The automobile sector is a cornerstone of China's economy, featuring a long industrial chain, wide coverage, and a strong employment drive (Peng et al., 2023). According to the China Automotive Chongqing Forum 2024 (CACS2024), China's total automobile output value reached 11 trillion RMB in 2023, accounting for nearly 10% of the national GDP and becoming the first economic pillar of China.

Based on data from the China Association of Automobile Manufacturers (CAAM), China's automobile production reached 30.161 million units in 2023, with sales reaching 30.094 million units. This achievement marks China's 15th consecutive year as the global leader in automobile production and sales, underscoring its status as a major player in the worldwide automobile market. Nonetheless, the Chinese automobile sector faces several challenges: it is notably deficient in independent research and development capabilities, with key components and technologies predominantly controlled by developed nations such as Germany and Japan. Additionally, the international influence of Chinese automotive brands remains limited (Tang, 2020). China's automobile industry needs further development and upgrades to boost its global competitiveness. This upgrading is crucial for improving international competitiveness, supporting related industries, and driving national economic growth (Jing, 2019).

In the context of economic globalization, an increasing number of multinational corporations are engaging in production and business activities worldwide. This has deepened inter-state division of labor and collaboration, segmented production systems, and extended industrial chains globally, thereby facilitating the formation of global value chains (Kano et al., 2020). GVC (Global value chain) significantly influences international trade, investment patterns, and the international competitiveness of enterprises (Qiang et al., 2021).

Few previous studies have explored how GVC affects the upgrading of China's automobile industry (CAI). As a pillar industry in China, how GVC influences the upgrading of CAI is worth studying. Several researchers have explored the connection between GVC and industrial upgrading. Some scholars believe that the participation of Chinese sectors in GVC promotes industrial upgrading. This participation allows Chinese industries to acquire the advanced management experience of enterprises in developed countries. This acquisition generates a knowledge spillover effect, boosting total factor productivity and thus facilitating industrial upgrading. (Criscuolo and Timmis, 2017; Yanikkaya et al., 2022). Some scholars believe that GVC inhibits China's industrial upgrading because China's participation in GVC is limited to the primary production link at the low end of the value chain. This positioning subjects it to the control of developed countries over the channels of independent research and development (RandD), potentially locking it into the low end of the GVC and thereby hindering industrial upgrading (Duan, 2023; Y. Li et al., 2020). Building on the analysis presented above, the way in which GVC influences the upgrading of CAI deserves further study.

Previous studies examining the impact of GVC on industrial upgrading have rarely incorporated mediating variables to investigate the underlying impact mechanisms. While GVC influences technology investment (Wang et al., 2021), and technology investment facilitates industrial upgrading (Jiang and Zhao, 2020). Therefore, this paper

examines whether GVC influences the upgrading of CAI through its effect on technology investment, considering technology investment as a mediating variable.

Foreign direct investment (FDI) plays a pivotal role in global value chain (GVC), particularly in producer-driven industries such as the automotive sector. Multinational corporations utilize FDI to access new markets and establish production bases, thereby driving industrial upgrading (Fernandes et al., 2022; Benabed, 2024). As a direct channel for transferring technology and knowledge, FDI enables multinational corporations to introduce advanced technologies, management practices, and production processes to host countries, essential for enhancing industrial competitiveness and promoting upgrading (Nosova, 2021). Furthermore, FDI provides substantial capital investments for building modern production facilities and infrastructure, offering a robust foundation for advancing the automotive industry (Yu et al., 2022). Given its critical role, FDI's moderating effect on the relationship between GVC and the upgrading of CAI merits closer examination. This study, therefore, designates FDI as a moderating variable to explore its influence in this context.

This study investigates how the global value chain influences the upgrading of CAI, utilizing provincial-level panel data from 2000 to 2020. Initially, the DEA-Malmquist model is employed to assess the upgrading of the automobile industry. Building on this analysis, the system GMM model is applied to investigate the influence of GVC on the upgrading process. Additionally, the research investigates how technology investment mediates the connection between GVC and the upgrading of China's automotive industry while examining the moderating effect of FDI.

Literature Review

Global Value Chain

Porter (1985) introduced the value chain concept in his book "Competitive Advantage." He explains that value chain analysis is a methodology for identifying activities within a firm. This involves subdividing the firm's activities into primary and support activities to identify and optimize value-added links, enhancing competitive advantage.

The global value chain (GVC) encompasses interconnected processes that span production, distribution, recycling, and disposal across national boundaries. It ultimately aims to realize the global value of goods and services. This concept encompasses all processes, from gathering and transporting raw materials to producing and distributing intermediate and finished goods and their ultimate use and recycling. A company is considered part of a GVC if it participates in any of these stages, with value added at each step and at least two steps occurring in different countries (UNIDO, 2002-2003; Antràs, 2020).

Additionally, the binary-driven theory of value chains categorizes them into two types: producer-driven and buyer-driven. In producer-driven value chains, large multinational producers, such as manufacturers or brands, exert strong market influence and technological capabilities, dominating the organization and coordination of the entire chain; this model is prevalent in industries like automotive and aerospace. Conversely, buyer-driven value chains are organized and coordinated by buyers, such as large

retailers or distributors, through orders and contracts, which is common in the apparel and footwear sectors (Gereffi, 1999).

Gereffi et al. (2005) identified five governance models for global value chains: market governance features loose buyer-seller relationships with pricing as the main coordination mechanism; modular governance allows for standardized production of modular items, simplifying transactions; relational governance relies on trust and frequent interactions to manage complex information exchanges; captive governance involves small suppliers heavily dependent on large buyers, facing high switching costs; and hierarchy governance resembles vertical integration, where firms control the entire production process internally. The automobile industry is a prime example of combining captive and relational governance, reflecting dependency and trust characteristics.

Industrial Upgrading

Industrial upgrading is pivotal in determining an industry's ability to achieve sustainable development and enhance comprehensive competitiveness. From a value chain perspective, industrial upgrading encompasses four methods: process upgrading, product upgrading, functional upgrading, and inter-sectoral upgrading. Process upgrading enhances production processes and technologies to boost efficiency and reduce costs. Product upgrading aims to enhance product quality or create new high-value products to meet market demands. Functional upgrading involves moving an enterprise from the low end of the value chain (such as production) to the high end (like design and marketing) to strengthen its position. Inter-sectoral upgrading refers to leveraging capabilities gained in one industry to enter new, higher value-added industries (Humphrey and Schmitz, 2002).

Industrial upgrading is a process in which an enterprise enhances its position and competitiveness in the global production network through optimal allocation of internal resources and effective integration of external resources (Kano, Tsang, and Yeung, 2020).

From a micro perspective, industrial upgrading enhances industrial quality and efficiency. This involves the optimal combination of production factors, advancements in technology and management, and improvements in product quality. From a macro perspective, industrial upgrading manifests as the enhancement of industrial structure, the coordinated development of industries, and the upgrading of structural elements. It also includes the continuous transfer of production resources from traditional sectors to emerging ones that offer higher added value (Li et al., 2010; Wang and Tang, 2021).

Upgrading China's automobile industry is essential for enhancing its competitiveness and promoting sustainable development. As a pillar of the national economy, this industry's upgrading is crucial for shaping the future of China's industrial system. The automobile sector significantly influences the economy through its strong industrial linkages, market expansion potential, and increased labor productivity. Furthermore, it contributes to rising consumer incomes and consumption levels, supporting overall economic stability (Zhou, 2018). Consequently, upgrading CAI is of critical importance.

Global Value Chain and China's Automobile Industry Upgrading

The relationship between GVC and industrial upgrading is complex, with some scholars asserting that GVC positively influences industrial upgrading. For instance, Tian et al. (2022) found that participation in GVC is a novel avenue for industrial advancement, highlighting that backward participation aids industrial upgrading in developing countries, while forward participation benefits developed nations. Additional studies indicate that developing nations have effectively upgraded their industries by enhancing labor productivity and acquiring skills (Pipkin and Fuentes, 2017). Pahl and Timmer (2020) noted that countries with lower productivity reap greater benefits from GVC participation, positively impacting productivity. Yanikkaya et al. (2022) further demonstrated that total factor productivity growth in manufacturing is significantly linked to the extent of a country's integration into GVC.

Conversely, there are arguments suggesting that GVC can inhibit industrial upgrading. Multinational corporations from developed countries maintain dominant positions in GVCs due to their technological and capital advantages, making it challenging for developing countries to move beyond low-end manufacturing (Huang and Zhang, 2015). This dynamic can trap developing nations in purchasing modularized solutions from developed countries, hindering their industrial upgrading efforts. Mao (2022) argued that such participation can harm emerging economies. Furthermore, Chinese industries have been "captured" at the low end of GVC, often dominated by large international buyers, which restricts their ability to advance beyond primary production (Ren et al., 2016; Timmer et al., 2014). This reliance on low-skilled labor and capital contributes to a low-end lock-in, stifling potential upgrading opportunities.

There is no consensus on how GVC influences industrial upgrading, highlighting the need for further research. This paper supports the idea that GVC may inhibit upgrading, especially in the automobile industry, which is characterized as a producer-driven value chain. Major multinational automobile companies dominate this sector due to their technological capabilities, positioning CAI at the low end of the GVC. Therefore, this paper proposes the following hypothesis 1:

H1 Global value chains inhibit the upgrading of China's automobile industry.

Mediating Role of Technology Investment

Integrating Chinese manufacturing into GVC demonstrates significant dependence and capture issues, which diminish the technology investment capacity of the sector. As firms increase their degree of embeddedness within GVC, they often gain access to high-quality imported intermediate inputs at a low cost; however, this reliance can undermine their innovation capabilities (Lv et al., 2018). Additionally, the local environment constrains firms' ability to acquire knowledge from GVC, and their dependence on these chains can further erode their intrinsic innovation capacity (De Marchi et al., 2018).

Chinese manufacturing firms primarily engage in the GVC division of labor through a captive governance model (Gereffi et al., 2005). In this context, upstream foreign industries possess stronger GVC governance capabilities and have incentives to exert direct control over the innovation behaviors of Chinese manufacturing firms by

supplying core technologies and intermediates (Arkolakis et al., 2018; Shen and Zheng, 2020). Technology investment can positively promote industrial upgrading, an important driving force (Jiang and Zhao, 2020; Wu and Liu, 2021). On this basis, this paper proposes hypothesis 2:

H2 Global value chain inhibits the upgrading of China's automobile industry by impacting technology investment.

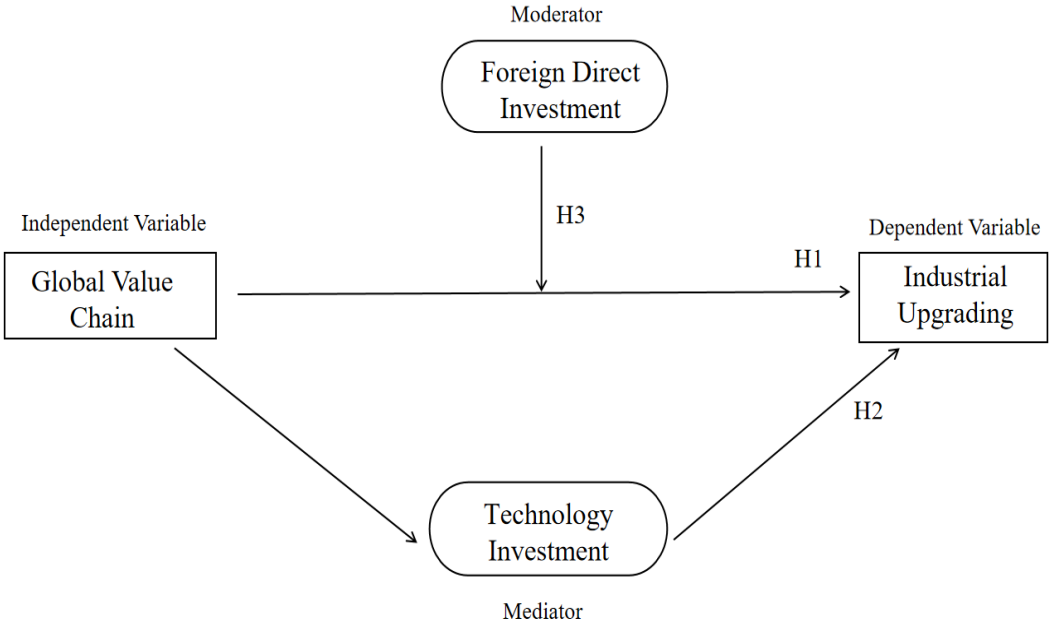
Moderating Role of Foreign Direct Investment

FDI inflows significantly enhance the positions of Belt and Road countries within the global value chain (He et al., 2021). A study of nine developing countries indicated that FDI overall boosts their participation in GVC and improves labor division (Yuan, 2018). Additionally, FDI contributes to sustainable economic development and industrial upgrading in these nations (Zhu and Wang, 2021). Scholvin (2023) noted that FDI strengthens regional GVC pillars, enabling local suppliers to upgrade and enhance their value capture, which aids economic growth. Increased intensity and breadth of FDI also significantly improve a country's GVC division of labor (Liu et al., 2019).

Regarding Chinese enterprises, Guo et al. (2020) and Zhang et al. (2021) found that FDI has notably improved the standing of local firms in the global value chain. Research by Zhang (2014) and Jiang (2019) on China's manufacturing sector showed that FDI significantly promotes overall value chain upgrading. Building on this, this paper puts forward the following hypothesis 3:

H3 FDI moderates the relationship between the global value chain and the upgrading of China's automobile industry.

Figure 1: Conceptual framework



Methodology

This paper utilizes data from the automobile industry across 28 provinces in China from 2000 to 2020, excluding provinces with incomplete data. The DEA-Malmquist method is employed to assess the upgrading of China's automotive sector. Recognizing that industrial upgrading is a dynamic process, the study applies the Generalized Method of Moments (GMM) to investigate how GVC influences the upgrading of CAI. Additionally, it investigates whether technology investment serves as a mediator in the influence of GVC on this upgrading process and whether foreign direct investment acts as a moderating factor.

Data Description

Measurement of Dependent Variable

Based on the studies of Sun and Xi (2015), Liu et al. (2017), and Xu (2020), this study uses total factor productivity (TFP) as the index for evaluating industrial upgrading. TFP effectively reflects advancements in the allocation of resources, technology, management, product quality, and structural adjustment, making it the best choice for this evaluation.

Data Envelopment Analysis (DEA) is a crucial technique for calculating TFP. This paper employs the DEA-Malmquist method based on Bhuyan et al. (2022) and Liu et al. (2023) to measure TFP. DEA, introduced by Charnes et al. (1978), is a non-parametric method for assessing the relative efficiency of input-output units by comparing actual production to an efficiency frontier. The Malmquist index, introduced by Malmquist (1953), measures productivity changes through distance functions, decomposing into efficiency change and technical change. The DEA-Malmquist method combines these approaches to evaluate efficiency changes over time, distinguishing between technical efficiency and technological progress. Proposed systematically by Färe et al. (1994), this method is valuable for industrial upgrading and resource optimization research. A DEA-Malmquist TFP greater than 1 indicates productivity growth, while less than 1 indicates a decline.

When using DEA to measure TFP in China's automobile industry, selecting appropriate input and output indicators is crucial. The input indicators consist of labor and capital. Labor input follows Jiang et al. (2018) and Qu and Meng (2022), measuring the annual average number of employees in the automobile sector with data from the China Industrial Statistics Yearbook (2001-2021). For capital input, this paper adopts the methodology of Fu (2020), considering the original value of fixed assets and total current assets and using data from the same yearbook, with 2000 as the base period for deflation.

The output index is based on Dan and Huiling (2017) and Lu and Wen (2018). It focuses on the total output value of the automobile industry from the China Automotive Industry Yearbook (2001-2021), again using 2000 as the base period for deflation. TFP is calculated using the DEA-Malmquist model, setting the base year TFP value to 1 and calculating subsequent values by multiplying the Malmquist index of each year by the previous year's TFP value (Du and Liu, 2023).

Measurement of Independent Variable

This paper uses the GVC position index from Koopman et al. (2010) to assess the degree of GVC embeddedness. It also incorporates methods from Yu and Gu (2016), Gonzalez et al. (2015), and Liu and Wu (2013) to derive the provincial GVC position index for China's automotive industry. The measurement formula is as follows:

$$\text{GVC-Position}_i = \ln\left(1 + \frac{IV * V_i/V}{E * T_i/T}\right) - \ln\left(1 + \frac{FV * V_i/V}{E * T_i/T}\right) \quad (1)$$

GVC-Position_i measures the global value chain position index for China's automobile industry in Province i. Vi and V denote the output values of the automobile industry for Province i and all of China, respectively, while Tj and T represent total exports for Province i and China. Data for these indicators are sourced from the China Statistical Yearbook and the China Automobile Industry Yearbook. IV, FV, and E indicate indirect value added, foreign value-added, and total value added from automotive exports, obtained from the OECD-TiVA 2023 database (C29 sector) updated until 2020. A higher GVC status index reflects a more prominent upstream role in the global value chain, suggesting a more significant impact on the global economy.

Measurement of Mediator and Moderator

The mediating variable in this study is technology investment, measured by RandD expenditure as outlined by Yu et al. (2023) and Wang et al. (2024). For the automobile industry, it is quantified by multiplying the proportion of RandD expenditure relative to each province's GDP by the total output value of that province's automobile industry. Data sources include the China Statistical Yearbook and the China Automotive Industry Yearbook.

The moderating variable is FDI, measured by calculating the proportion of annual automobile output value in each province's GDP, then multiplying by total foreign direct investment in the industry, following Shen (2017). Data are also sourced from the China Statistical Yearbook and the China Automotive Industry Yearbook.

Measurement of Control Variables

Based on previous studies, this paper selects industrial agglomeration (Aritenang, 2021), human capital (Nouira and Saafi, 2022), and government intervention (Damstra et al., 2021) as control variables. Industrial agglomeration is measured using the location entropy index, following Zhang et al. (2023). Human capital is assessed by the average years of schooling (Suhendra et al., 2020), while government intervention is evaluated using the ratio of regional government budget expenditures to GDP (Blancheton and Chhorn, 2021). The existing control variable for government intervention may not fully capture the specific nuances and support directed at the automobile industry. This is a limitation of the study.

Model Specification

Industrial upgrading is a dynamic process influenced by past developments. To account for this, this paper constructs a dynamic panel model by introducing a lagged dependent variable for industrial upgrading (Wiryawan et al., 2023). The system GMM approach

addresses potential endogeneity issues from lagged variables. This model analyzes how GVC influences the upgrading of CAI, the mediating role of technology investment, and the moderating role of foreign direct investment.

The analysis uses data from 28 Chinese provinces over a 21-year period (2000-2020), excluding those with missing data. Given the GMM model's requirement for short panel data (N > T), the data is averaged over three-year intervals, resulting in 7 data periods. This approach increases the gap between N and T, enhancing the validity of the GMM model.

Baseline Model

To examine the direct influence of GVC on the upgrading of CAI, this paper, based on Nassir (2023), proposes baseline Model 1 as follows:

$$Upgrade_{i,t}=\alpha_0+\alpha_1 Upgrade_{i,t-1}+\alpha_2 GVC_{i,t}+\alpha_3 AGG_{i,t}+\alpha_4 HC_{i,t}+\alpha_5 GOV_{i,t}+\varepsilon_{i,t} \quad (2)$$

In this equation, $Upgrade_{i,t}$ is the dependent variable, indicating the level of automobile industry upgrading in province i during year t. $Upgrade_{i,t-1}$ represents its lagged value, while $GVC_{i,t}$ is the independent variable denoting the global value chain in province i during year t. The control variables $AGG_{i,t}$, $HC_{i,t}$, and $GOV_{i,t}$ refer to industrial agglomeration, human capital, and government intervention in province i for year t, respectively. α_0 is the constant term and $\varepsilon_{i,t}$ is the random error term.

Mediating Effect Model

To examine the mediating role of technology investment between GVC and the upgrading of CAI, this paper develops a mediating effect model based on Yang et al. (2023). The mediating model 2 is formulated as follows:

$$TI_{i,t}=\beta_0+\beta_1 TI_{i,t-1}+\beta_2 GVC_{i,t}+\beta_3 AGG_{i,t}+\beta_4 HC_{i,t}+\beta_5 GOV_{i,t}+\varepsilon_{i,t} \quad (3)$$

$$Upgrade_{i,t}=\gamma_0+\gamma_1 Upgrade_{i,t-1}+\gamma_2 GVC_{i,t}+\gamma_3 TI_{i,t}+\gamma_4 AGG_{i,t}+\gamma_5 HC_{i,t}+\gamma_6 GOV_{i,t}+\varepsilon_{i,t} \quad (4)$$

In these equations, $TI_{i,t}$ represents the mediating variable, technology investment in province i during year t, with $TI_{i,t-1}$ as its lagged value. β_0 and γ_0 are constant terms, while β_1-β_5 and γ_1-γ_6 are estimated coefficients. Based on Yang et al. (2023), if both β_2 and γ_3 are significant, it would indicate that technology investment mediates the impact of GVC on the upgrading of CAI.

Moderating Effect Model

To verify the moderating role of FDI between GVC and the upgrading of CAI, the moderating model 3 is formulated as follows:

$$Upgrade_{i,t}=\theta_0+\theta_1 Upgrade_{i,t1}+\theta_2 GVC_{i,t}+\theta_3 GVC_{i,t}*FDI_{i,t}+\theta_4 FDI_{i,t}+\theta_5 AGG_{i,t}+\theta_6 HC_{i,t}+\theta_7 GOV_{i,t}+\varepsilon_{i,} \quad (5)$$

In this equation, $FDI_{i,t}$ is the moderating variable, representing foreign direct investment in province i during year t. $GVC_{i,t}*FDI_{i,t}$ denotes the interaction between GVC and FDI.

θ_0 is the constant term, while θ_1-θ_7 are estimated coefficients, with θ_3 representing the interaction term's coefficient. If both θ2 and θ3 are significant, it indicates that FDI moderates the impact of GVC on the upgrading of CAI.

Results

Descriptive Statistics

Table 1 displays the descriptive statistics for all variables analyzed in this study. The average value for industrial upgrading is 3.0704, with a standard deviation 2.3097. The recorded minimum and maximum values are 0.2768 and 15.1788, respectively, indicating significant variability in industrial upgrading across different provinces in China. The global value chain ranges from 0.0132 to 1.3025, with a mean of 0.5830 and a standard deviation of 0.2819, showing a relatively low degree of dispersion. Meanwhile, the mean values for technology investment and foreign direct investment are 2.5193 and 2.8040, with standard deviations of 5.1349 and 4.4684, respectively.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std.dev.	Min	Max
Upgrade	196	3.0704	2.3097	0.2768	15.1788
GVC	196	0.5830	0.2819	0.0132	1.3025
TI	196	2.5193	5.1349	0.0006	29.2029
FDI	196	2.8040	4.4684	0.0002	27.3320
AGG	196	1.1627	1.4262	0.0119	8.5466
HC	196	8.6542	1.0744	6.0535	12.5817
GOV	196	0.1937	0.0770	0.0757	0.4575

DEA Results

This study employs the DEA-Malmquist method to assess the total factor productivity (TFP) of China's automobile industry across 28 provinces from 2000 to 2020, serving as a proxy for industrial upgrading. The analysis is conducted using Deap2.1 software. Table 2 presents the annual average rates of change in total factor productivity and its decomposition for China's automobile industry from 2000 to 2020. Table 2 shows that from 2000 to 2020, the annual average rate of change in total factor productivity for the Chinese automobile industry was 1.063, with technical efficiency and technological change rates at 1.028 and 1.034, respectively. This indicates a 6.3% increase in TFP, driven by a 2.8% growth in technical efficiency and a 3.4% growth in technological progress. Notably, TFP growth was negative during 2007-2008, 2010-2012, 2013-2014, and 2017-2020, while it was positive in other years.

Table 2: Change and decomposition of total factor productivity in China's automobile industry of annual means, 2000-2020

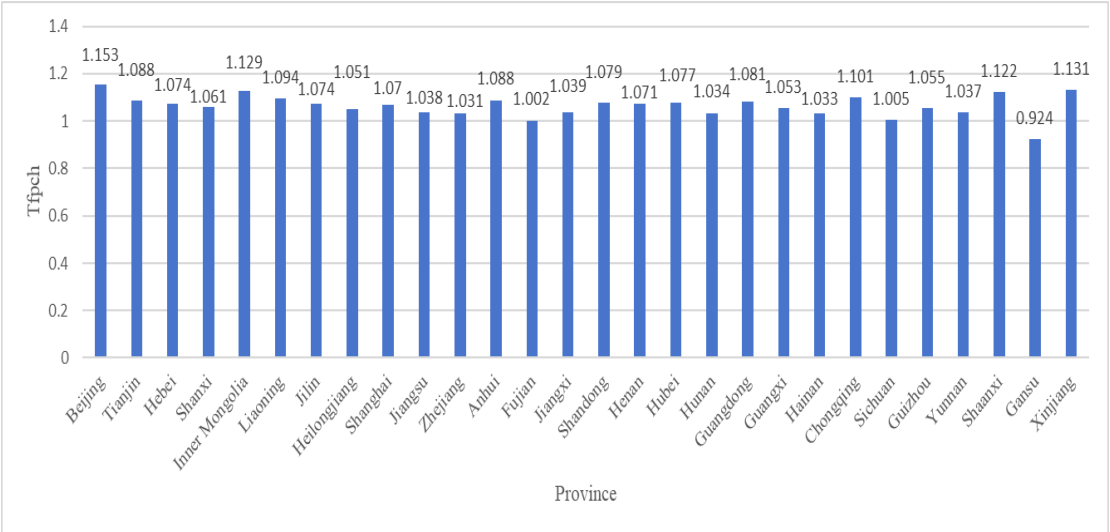
Year	Effch	Techch	Tfpch
2000-2001	1.068	1.134	1.211
2001-2002	0.968	1.390	1.346
2002-2003	1.381	0.812	1.121

Year	Effch	Techch	Tfpch
2003-2004	0.849	1.183	1.005
2004-2005	1.418	0.753	1.069
2005-2006	1.011	1.135	1.148
2006-2007	1.127	0.956	1.078
2007-2008	0.812	1.176	0.955
2008-2009	0.982	1.172	1.151
2009-2010	1.217	0.842	1.025
2010-2011	0.798	1.068	0.852
2011-2012	1.038	0.961	0.997
2012-2013	1.005	1.022	1.026
2013-2014	0.982	0.995	0.977
2014-2015	1.141	0.926	1.057
2015-2016	1.218	1.306	1.591
2016-2017	1.057	0.985	1.042
2017-2018	0.864	1.084	0.937
2018-2019	0.723	1.315	0.950
2019-2020	1.229	0.763	0.938
Mean（2000-2020）	1.028	1.034	1.063

Note: Techch is the technological change; Effch is the technical efficiency change; TFPch is the total factor productivity change

Figure 2 presents the average total factor productivity change rate for 28 provinces in China. Most provinces exhibit TFP change rates greater than 1, while Gansu Province stands out with a rate of 0.924, indicating negative TFP growth in the automobile sector. In contrast, all other provinces show positive TFP growth. Notably, Beijing has the highest TFP change rate at 1.153.

Figure 2: Change in total factor productivity of the means of 28 provinces in China's Automobile Industry



Overall, China's automobile industry's total factor productivity is growing. However, in certain years and provinces, productivity growth falls below 1, indicating negative

growth. This suggests significant room for improvement in total factor productivity within China's automobile industry, indicating the need for further development to achieve comprehensive sector upgrading.

GMM Results

This study utilizes the System GMM method to investigate the impact of global value chains on the upgrading of CAI. The System GMM approach addresses estimation bias by constructing instrumental variables correlated with endogenous explanatory variables but uncorrelated with the error term. In this paper, GMM instrumental variables are generated from lagged values (including lagged dependent variables and other endogenous explanatory variables) to address endogeneity issues. The current error term does not influence these lagged values. However, they correlate with the endogenous variables, effectively mitigating bias caused by the lagged dependent variable and endogenous explanatory variables. The regression analysis was conducted using Stata software. Table 3 demonstrates the regression results of the baseline model and mediating model.

Table 3: Baseline effect and mediating effect results

Variable	Upgrade Column (1)	TI Column (2)	Upgrade Column (3)
L1.Upgrade	0.7333*** (0.0287)		0.6839*** (0.0303)
L1.TI		0.9268*** (0.0608)	
GVC	-1.4882*** (0.3466)	-3.8177** （1.8502）	-3.2233*** (0.4769)
TI			0.1727*** (0.0183)
AGG	0.7727*** (0.0325)	1.3710*** (0.3606)	0.9077*** (0.0894)
HC	0.5918*** (0.0795)	2.1801*** (0.5187)	0.0948 (0.0971)
GOV	3.2990*** (0.3315)	-5.1056 (3.6310)	5.1830*** (0.7274)
Constant	-4.6560* (0.5596)	-16.4444*** (3.4999)	-0.1156 (0.7771)
Number of groups	28	28	28
Number of instruments	27	13	27
AR(1)	0.044	0.087	0.056
AR(2)	0.401	0.150	0.470
Hansen	0.222	0.184	0.235

Note: 1. Figures in parentheses are standard errors. 2. ***, ** and * indicates significant at 1%, 5% and 10% level of significance

The P-values for AR(1) and AR(2) in Table 3 indicate that AR(1) is less than 0.1, whereas AR(2) exceeds 0.1, confirming the absence of second-order autocorrelation in the disturbance terms. Furthermore, the P-values from Hansen's test, greater than 0.1, suggest that the instrumental variables do not suffer from over-identification issues. Consequently, the system GMM models for both the baseline and mediating models are deemed valid regarding the lagged coefficient of the dependent variable, L1. Upgrade

is positive and significant at the 1% level. This indicates that past industrial upgrading positively influences current upgrading, supporting the validity of the dynamic panel framework.

Column (1) is the baseline model regression result. It shows that the coefficient for the independent variable, the global value chain, is -1.4882 and is significant at the 1% level. This finding indicates that the global value chain negatively impacts the upgrading of China's automobile industry, thereby confirming Hypothesis 1. Specifically, a 1% increase in GVC corresponds to a 1.4882% decrease in industrial upgrading. This represents the total effect of GVC on industrial upgrading. In addition, the control variables of industrial agglomeration, human capital, and government intervention have significantly promoted the upgrading of China's automobile industry. Column (2) investigates how GVC influences technology investment. Here, the coefficient for GVC is -3.8177, which passes the 5% significance test. This indicates that participation in GVC adversely affects technology investment in China's automotive sector. Specifically, a 1% increase in GVC corresponds to a 3.8177% decline in technology investment.

Column (3) reports a coefficient of 0.1727 for technology investment, which is statistically significant at the 1% level. This result indicates that technology investment positively influences the upgrading of China's automotive industry, with a 1% increase in technology investment resulting in a 0.1727% increase in industry upgrading.

Together, these results from Columns (1), (2), and (3) confirm that GVC inhibits the upgrading of CAI by constraining technology investment, thereby validating Hypothesis 2.

This paper utilizes the system GMM method to further investigate the moderating role of FDI between GVC and the upgrading of CAI. The results are presented in Model 3, as shown in Table 4. The P values of AR(1), AR(2), and Hansen's test indicate that the system GMM model for the mediating effect is valid.

Table 4: Moderating effect results

Variable	Upgrade Model 3
L1.Upgrade	0.6460*** (0.0518)
GVC	-4.0126*** (0.6021)
FDI_GVC	0.6108*** (0.1323)
FDI	-0.2363* (0.1281)
AGG	1.0555*** (0.1008)
HC	0.1555 (0.1266)
GOV	3.7099*** (0.6317)
Constant	0.0344

Variable	Upgrade Model 3
	(0.9911)
Number of groups	28
Number of instruments	27
AR(1)	0.072
AR(2)	0.173
Hansen	0.332

Note: 1. Figures in parentheses are standard errors. 2. ***, ** and * indicates significant at 1% , 5% and 10% level of significance. 3.FDI_GVC is the interaction term between FDI and GVC

In Table 4, the coefficient of the interaction term between FDI and GVC denoted as FDI_GVC is 0.6108. This result is significant at the 1% level, suggesting that FDI does indeed moderate the impact of GVC on the upgrading of CAI. Specifically, a higher level of FDI in China's automotive industry weakens the negative effects of GVC on industrial upgrading, thereby facilitating the advancement of the industry.

Discussion

This paper examines how GVC influences the upgrading of China's automobile industry. The DEA-Malmquist method is utilized to assess the total factor productivity of the automobile sector across 28 provinces in China, serving as a proxy for industrial upgrading. Additionally, a dynamic panel system GMM model is employed to analyze the effects of GVC on the automotive industry, focusing on mediating the effect of technology investment and moderating the effect of foreign direct investment.

The regression results of the baseline model indicate that the global value chain negatively affects the upgrading of CAI. This is a result of the phenomenon of low-end lock-in. China's automotive sector is primarily positioned in the low-end segment of the global value chain, while the high-end segment is predominantly controlled by multinational corporations from developed nations (Wei et al., 2020). This dynamic creates a situation where China's automobile industry is constrained by developed countries, trapping it in a low-end lock-in effect that obstructs its path to upgrading.

Based on the mediation model analysis, this study concludes that technology investment is a mediator between GVC and the upgrading of CAI. The results of the mediation effect can be reasonably interpreted as follows: First, once the Chinese automobile industry becomes embedded in the GVC, it is progressively influenced by multinational corporations from developed countries, which can control the channels for independent research and development. This dynamic ultimately reduces the capacity for independent innovation among Chinese firms. Whenever these companies seek to pursue independent research and development of technological innovation, their efforts are often impeded by the presence of these developed country multinationals (Buckley, 2021; Pietrobelli et al., 2021; Xie et al., 2023). Furthermore, after embedding in the global value chain, Chinese firms cheaply access high-quality imported intermediate inputs. This access undermines their innovation capabilities and fosters a strong technological dependence on developed countries (De Marchi et al., 2018; Lv et al., 2018). Consequently, this reliance diminishes the motivation for technology investment within China's automobile industry.

Conversely, technology investment is a critical pathway for overcoming low-end lock-in and is a key factor driving industrial upgrading (Aboal et al., 2015; Zhou et al., 2022). Therefore, when considered collectively, embedding in global value chains inhibits technology investment, consequently hindering industrial upgrading.

The findings from the moderating effect analysis show that foreign direct investment significantly moderates the influence of the GVC on the upgrading of CAI. This is largely attributed to FDI's ability to address capital shortages (Manova et al., 2015). By alleviating the relative deficiencies in capital, technology, and knowledge, FDI enables Chinese local enterprises to leverage technological spillovers from foreign investments (Fernandes et al., 2022; Su and Fu, 2021). Given that RandD, design, and high-technology production processes in the upstream segments of the global value chain typically require substantial capital investment, the influx of foreign capital can provide essential financial support for firms aiming to ascend the global value chain (Tang and Zhang, 2018). This support helps mitigate the challenges associated with low-end lock-in, facilitating upgrading China's automotive industry.

Practical Implications for Asian Business

The findings from this study about upgrading China's automotive industry offer several critical implications for businesses operating in Asia, particularly within the automotive sector. A detailed exploration of these implications can guide firms in navigating the challenges and opportunities presented by the global value chain.

Asian automotive firms should thoroughly assess their roles within the global value chain to navigate competitive landscapes effectively. It is crucial to understand whether they operate in low-end segments or have the potential for higher-value activities, as this informs their strategic decision-making. To facilitate a transition towards higher-value offerings, companies should prioritize product differentiation through investments in distinctive characteristics, enhanced quality, and outstanding customer support, thereby establishing a distinct brand identity in a crowded market. Simultaneously, actively pursuing market diversification into emerging markets or niche segments that demand innovative solutions can reduce reliance on established markets often dominated by multinationals and open up new revenue streams. By leveraging their capabilities in innovation and quality, firms can tailor strategies to meet the specific needs of diverse consumer bases. Continuous market research and adaptation to local contexts will further enhance their competitive positioning within the global value chain, enabling them to respond agilely to changing market dynamics and consumer trends.

To remain competitive in the automotive industry, Asian businesses can focus on investment in technological innovation by committing to enhancing their research and development (RandD) capabilities through increased RandD expenditure, forming dedicated innovation teams, and collaborating with universities and research institutions. Fostering an organizational culture that encourages creativity and risk-taking is equally important; firms can achieve this by establishing internal innovation competitions or incubators to generate new ideas and technologies tailored to the automotive sector. Additionally, engaging in open innovation strategies, such as

crowdsourcing ideas and collaborating with startups, can further accelerate the innovation process and lead to the development of groundbreaking automotive technologies. By integrating these approaches, Asian automotive companies can create a robust framework for continuous innovation that drives growth and strengthens their position in the global market.

Leveraging foreign direct investment is crucial for Asian automotive firms seeking to enhance their competitiveness and growth. To achieve this, these companies should seek strategic foreign investors who can provide capital, valuable technological expertise, and access to new markets. Establishing joint ventures or partnerships with these investors can facilitate technology transfer and knowledge sharing, allowing firms to innovate more rapidly and effectively. Additionally, companies must stay informed about government policies and incentives to attract FDI. By aligning their business strategies with these initiatives, firms can maximize their ability to attract foreign capital, further bolstering their RandD efforts and enhancing their overall market position. Through these strategic approaches to leveraging FDI, Asian automotive companies can significantly strengthen their competitive edge in an increasingly globalized market.

By implementing these comprehensive strategies, Asian businesses, particularly in the automotive industry, can enhance their resilience and competitiveness within global value chains. This strategic approach will facilitate their upgrading efforts and position them to thrive in an increasingly complex and dynamic marketplace.

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