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How Does Trade Policy Uncertainty Affect Supply Chain Efficiency: A Case Study of Listed Companies of Chinese Port Industry

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Abstract: This paper uses a data sample from listed companies in the national port industry from 2007 to 2020 to systematically explore the impact of trade policy uncertainty on the supply chain efficiency of listed companies in the national port industry and its mechanism based on the events of Sino–US trade policy changes. It is found that the increase in trade policy uncertainty significantly reduces the enterprises' supply chain efficiency. The further influence channel test shows that the increase of trade policy uncertainty inhibits the improvement of enterprises' supply chain efficiency by reducing the export quantity and technological innovation channel of enterprises. From the perspective of trade policy changes, this paper provides a new explanation for understanding the dynamic changes in the supply chain efficiency of Chinese enterprises in recent years and enriches relevant research on evaluating the economic effects of trade policy uncertainty.

Keywords: trade policy uncertainty; supply chain efficiency; exports quantity; technological innovation

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1. Introduction

In recent years, with the intensification of economic and trade frictions and trade protectionism, the continued spread of COVID-19, and the outbreak of the Russia–Ukraine war, the vulnerability of the global supply chain has been laid bare. In the context of increasing instability and uncertainty of the world economy, the sustainable development of China's economy largely depends on whether related industries can ensure the stability and security of the supply chain. The report of the Communist Party of China's 20th National Congress stresses that ensuring the security of food, energy, resources, and important industrial and supply chains is an important part of maintaining economic security. To ensure that all links of the national economy are effectively connected smoothly, with industrial supply chains being continuously linked, neither blocked nor rigid, which will promote the efficiency of the supply chain from a macro level [1], thus ensuring the stability and security of the supply chain. From a micro perspective, the use of institutional and technological innovation to promote the efficiency of enterprises in all aspects, form the core competitiveness and market power of enterprises and thus ensure the unhindered circulation of the industrial supply chain [2], which is also an important path to ensure the stability and security of the Chinese supply chain by promoting the improvement of supply chain efficiency. At the same time, as the world's largest trading power, about 95% of China's international trade of goods is completed by sea, so the role of ports cannot be underestimated. With the further deepening of economic globalization and international division of labor, the port has developed into an important industry related to the lifeblood of the whole national economy, which greatly promotes the development of the national economy and foreign trade. As an important industry related to the lifeblood of the whole national economy, the effective connection, smooth flow and efficiency improvement of

the port industry will play an important role in ensuring the stability and security of the supply chain. In fact, scholars have confirmed the key node role of ports in supply chains and the importance of ports to foreign trade, respectively [3–5].

At the same time, the current severe recession of the world economy and the continuous contraction of external demand is likely to trigger a new round of trade friction between the United States and other countries [6]. Trade frictions greatly increase Trade Policy Uncertainty (TPU). In 2017, the uncertainty index of China's trade policy reached the highest point in history and then soared in successive years [7]. The index of trade policy uncertainty in 2019 increased by 212% compared to 2017, reaching a record high. The uncertainty of macro trade policy will affect enterprises' expectations of the future market trend and subsequently affect the enterprises' daily operational behavior. Regarding the impact of trade policy uncertainty on micro-enterprises, existing studies mainly focus on import and export, total factor productivity, profit rate, innovation, and other aspects of enterprises [8–13], lacking a probe into the micro-enterprise-supply chain efficiency. As an important subject involved in port economic construction, the efficient operation of port enterprises has always been a concern of the government and enterprises [14]. By improving their own efficiency in each link, port enterprises can ensure the smooth and efficient supply chain of the port industry, promote the improvement of the efficiency of the port industry supply chain, and finally guarantee the security and stability of the supply chain of our country. However, China's foreign trade is confronted with increasingly complex domestic and foreign situations at present. With the increasing instability and uncertainty, it will seriously interfere with the continuity and stability of the production and operation of port enterprises in each link, hindering the smooth and efficient operation of the industrial supply chain and thus threatening the security and stability of China's supply chain. Therefore, in this context, exploring how trade policy uncertainty affects the supply chain efficiency of port enterprises will have important theoretical and practical significance for actively coping with the complex and changeable international situation, deeply implementing the domestic and international dual-cycle development strategy, and building a new system of a high-level open economy.

In the study of supply chain efficiency, most scholars focus on the measurement and mining of influencing factors of supply chain efficiency [15–18]. Few kinds of literature consider the relationship between foreign trade and supply chain efficiency [1]. Existing studies ignore the role played by foreign trade in improving supply chain efficiency, and rarely explain the influence mechanism of trade policy uncertainty on supply chain efficiency from different paths. In view of this, in order to reveal the impact and mechanism of trade policy uncertainty on supply chain efficiency, this paper uses data from listed companies in the national port industry to focus on exploring two key issues: Firstly, whether trade policy uncertainty directly affects supply chain efficiency of enterprises, and secondly, what is the channel path that trade policy uncertainty affects the efficiency of enterprises' supply chain?

The possible marginal contributions of this paper are as follows. First, we examine the influencing factors of the supply chain efficiency of enterprises from the perspective of trade policy changes, which is conducive to a more comprehensive understanding of the driving factors of supply chain efficiency changes of Chinese enterprises, and also helps to systematically evaluate the economic effects of trade policy uncertainty changes. Second, this paper incorporates macro trade policies into a unified analysis framework, systematically examines its relationship with the efficiency of enterprises' supply chain, and finds that the increase of trade policy uncertainty can significantly reduce the efficiency of enterprises' supply chain, which has important policy implications for how to improve the core competitiveness and market power of Chinese enterprises. Last, we use the intermediary effect model to test the mechanism that trade policy uncertainty affects the efficiency of enterprises' supply chain so as to find that export quantity and technological innovation are two possible channels that trade policy uncertainty affect the efficiency

of enterprises' supply chain, which help to better understand the internal relationship between trade policy uncertainty and enterprises' supply chain efficiency.

The rest of the paper is organized as follows: Section 2 presents the mechanism analysis and research hypotheses. Section 3 describes measurement models, index measurement, and data processing. Section 4 outlines the empirical test results. Section 5 analyzes the influencing mechanism. The final section is the conclusion.

2. Theoretical Analysis and Research Hypothesis

Christopher (1998) [19] believes that a supply chain is an organization that can play a linking role in upstream and downstream activities and generates value in the form of providing goods and services to final customers. This view shows that proper management can improve the efficiency of any link in the supply chain. Qrunfleh and Tarafdar (2013) [20] found that a supply chain can effectively integrate suppliers, manufacturers, warehouses and stores so as to ensure that the goods produced can be reasonably distributed at the right time and place. In addition, the costs can be minimized under the requirement of service level, which helps to improve supply chain efficiency. According to the description of the definition of the supply chain, for micro-enterprises, reducing enterprise inventory and reducing enterprise costs without affecting the service level is the key to improving the efficiency of the supply chain.

In view of this, we explore the influence of trade policy uncertainty on the supply chain efficiency of listed companies in the national port industry from two aspects of export quantity and technological innovation.

2.1. Export Quantity Channels

The aggravation of trade policy uncertainty will increase the sunk costs of enterprises and restrain their export tendency [21], thus leading to a decline in the quantity and types of enterprises' exports [22,23]. When the number of products produced by an enterprise is fixed, the increase in export quantity is positively correlated with the inventory turnover rate of the enterprise. In other words: the greater the export quantity, the more conducive to improving the inventory turnover rate of the enterprise, thus reducing the inventory of the enterprise [24]. To sum up, the intensification of trade policy uncertainty will reduce the inventory turnover rate of enterprises by reducing the number of export products, increasing the inventory, and ultimately leading to the decline of the efficiency of enterprises' supply chains.

2.2. Technological Innovation Channels

The related literature show that the decrease in trade policy uncertainty significantly promotes the innovation activities of enterprises [10,13,25]. Innovation consists of process innovation and product innovation. Process innovation can effectively reduce production costs and thus generate scale effects, promote the improvement of labor productivity, and ultimately improve product quality. Product innovation enhances the degree of specialization of the product itself, thus promoting the improvement of product quality [26]. The improvement of product quality is more conducive to exports externally, while internally, it can enhance the company's reputation, increase product sales, reduce inventory, and thereby improve the efficiency of the company's supply chain [2]. The decline of trade policy uncertainty has the competitive incentive effect [27]. Fierce market competition will stimulate the R&D and innovation motivation of enterprises. In order to seize more market shares, enterprises will vigorously improve the original products and develop new products, putting forward higher requirements on the quality of their own products and hoping to obtain more market shares through high-quality products. To sum up, the intensification of trade policy uncertainty reduces product quality and product sales while increases enterprises' inventory by inhibiting enterprises' technological innovation, thus reducing the efficiency of enterprises' supply chains.

Based on the above analysis, we propose three research hypotheses:

Hypothesis 1 (H1). *The increase in trade policy uncertainty reduces the efficiency of enterprises' supply chain.*

Hypothesis 2 (H2). *The increase in trade policy uncertainty slows down enterprises' inventory turnover and increases enterprises' inventory by reducing export quantity, thus reducing the efficiency of enterprises' supply chains. In other words, there is a transmission path of "trade policy uncertainty—export quantity—enterprises' supply chain efficiency".*

Hypothesis 3 (H3). *The increase in trade policy uncertainty reduces product quality and product sales while increasing enterprises' inventory by inhibiting technological innovation, thus reducing the efficiency of enterprises' supply chains. In other words, there is a transmission path of "trade policy uncertainty—technological innovation—enterprises' supply chain efficiency".*

The internal mechanism of trade policy uncertainty affecting the efficiency of enterprises' supply chains is shown in Figure 1.

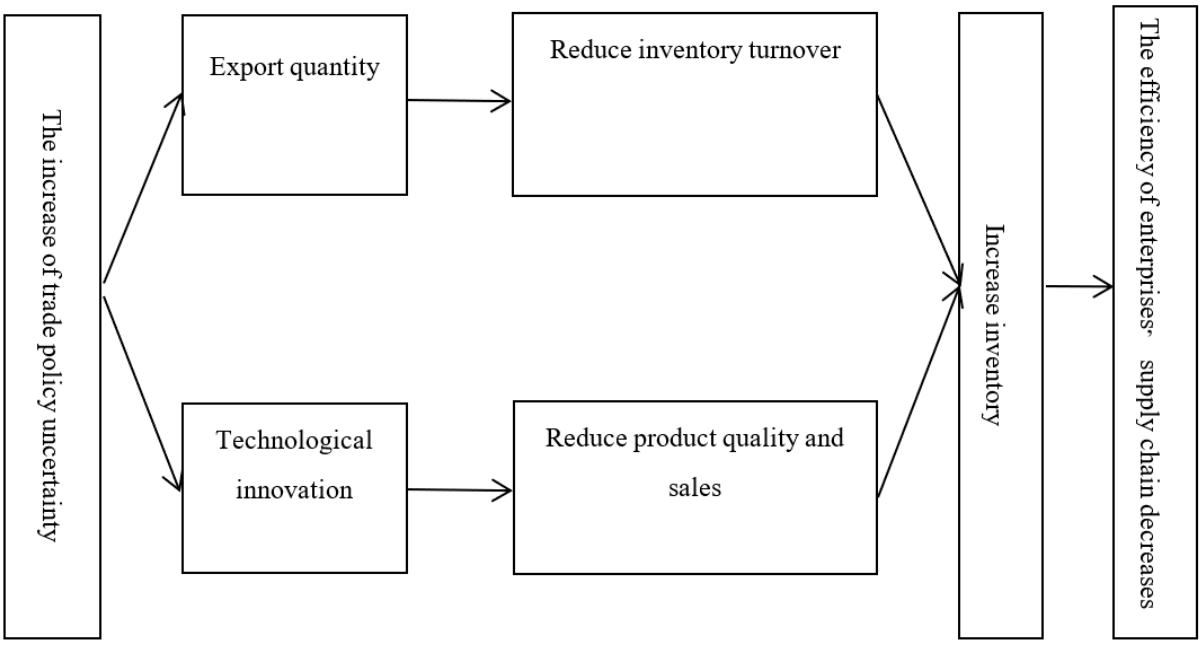

Figure 1. Internal mechanism of trade policy uncertainty affecting the efficiency of enterprise's supply chain.

3. Research Design

3.1. Measurement Model Setting

In order to explore the impact of trade policy uncertainty on the supply chain efficiency of listed enterprises in the port industry, we use the research ideas of Dongdong Cai et al. (2021) [28] and take the event that enterprises with a higher proportion of exports will experience a greater increase in trade policy uncertainty after the change of Sino–US trade policy as exogenous policy impact. The year 2016 is taken as the time node to identify changes in trade policy uncertainty. The logic of the empirical test with the Differences-in-Differences (DID) model is that after the change of Sino–US trade policies, enterprises with a relatively high proportion of exports before 2016 will experience a greater increase in trade policy uncertainty. Before 2016, the export ratio of enterprises was formed, and the export ratio is generally determined by the ability and characteristics of enterprises. Although there is a certain degree of time variability, such variability will not change systematically or significantly in the short term in general but can only have a long-term trend with relatively strong exogeneity. Therefore, based on 2016 as the time node, we set

the samples as the control group and the treatment group and set the following benchmark DID model:

$$EFF_{it} = \alpha_0 + \alpha_1 TradePU_{i15} \times PostTrump16_t + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (1)$$

where i denotes enterprise, and t denotes the year. EFF_{it} represents the enterprise supply chain efficiency in the period. $TradePU_{i15}$ is the trade policy uncertainty index of each enterprise in 2015. $PostTrump16_t$ is the time dummy variable, the year 2016 and later is 1, and the year before 2016 is 0. The estimated coefficient α_1 of the interaction term $Tradepu_{i15} \times PostTrump16_t$ measures the average difference between the supply chain efficiency of enterprises with high export share and those with low export share before and after 2016. It characterizes the causal effect between the increase of TPU and the supply chain efficiency of enterprises. Specifically, if $\alpha_1 < 1$, it indicates that the supply chain efficiency of export-oriented enterprises decreases compared with that of enterprises with a lower share of export. That is, the increase in trade policy uncertainty reduces the supply chain efficiency of enterprises. If $\alpha_1 > 1$, it indicates that the increase in trade policy uncertainty improves the supply chain efficiency of export-oriented enterprises. X_{it} represents control variables, including the enterprise scale (*scale*). We take the natural logarithm of the enterprise's sales volumes as the scale of the firm. The enterprise's (*age*) is calculated by the difference between the year of the current year and the year of establishment of the enterprise. The enterprise's finance constraint (*loan*) is calculated by taking the natural logarithm of the ratio of accounts receivable to total fixed assets. The enterprise's profit rate (*pro*) is expressed as the natural logarithm of the ratio of total profit to operating cost. In addition, considering the possibility of missing explanatory variables in the empirical model, which may cause bias in the test results, in order to effectively reduce the biased influence, we also control the firm fixed effect φ_i and year fixed effect θ_t in the estimation model, ε_{it} is the random disturbance term.

3.2. Measurement of Key Variables

3.2.1. Trade Policy Uncertainty (TPU)

Using the research ideas of Dongdong Cai et al. (2021) [28], trade policy uncertainty (TPU) in this paper is calculated by multiplying the export proportion of listed enterprises in the port industry by the trade policy uncertainty index (TPU) of the current year. The trade policy uncertainty index (TPU) is averaged by referring to the monthly TPU index calculated by Baker et al. (Scott R. and Baker of the Kellogg School of Management at Northwestern University, Nick Bloom of Stanford University and Steven J. Davis of the University of Chicago have measured monthly economic policy uncertainty (EPU) and trade policy uncertainty (TPU) indices for countries around the world, and publish on http://www.policyuncertainty.com/about.html) to obtain the annual value.

3.2.2. Enterprise's Supply Chain Efficiency (EFF)

Three-stage DEA model was used to evaluate the supply chain efficiency of listed companies in the port industry. The selection indexes of input, output and environment variables are shown in Table 1 below. The data come from annual reports of listed port enterprises 2007–2020, CSMAR Database, China Port Statistical Yearbook, etc.

Table 1. The selection indexes of input, output and environment variables.

Variables	Indicators	Unit
Input variables	Employee	Person
	Fixed asset	Hundred million yuan
	Operating cost	Hundred million yuan

Table 1. *Cont.*

Variables	Indicators	Unit
Output variables	Net profit	Hundred million yuan
	Cargo throughput	Ten thousand tons
	NOX emission	Ten thousand tons
Environmental variables	Local GDP per capita	Yuan
	Age of establishment of enterprise	Year
	Scale of asset	Hundred million yuan

3.2.3. Sources of Data

This article takes listed companies in the national port industry from 2007 to 2020 as the research sample, and the research data is sourced from the annual reports of listed companies, the CSMAR Database, the China Port Statistical Yearbook and provincial and municipal statistical yearbooks. Considering the availability and reliability of the data of the listed companies in the port industry, 138 pieces of data from 17 listed companies in the port industry are obtained by eliminating the listed companies with missing data. Descriptive statistics of the main variables are shown in Table 2:

Table 2. Descriptive statistics of main variables.

Variable Name	Variable Meaning	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
TPU	Trade policy uncertainty	138	385.3814	1332.508	1.36	10,234.45
EFF	Enterprise's supply chain efficiency	138	0.8036	0.2352	0.24	1
scale	Enterprise's scale	138	274.5025	310.778	6.11	1559.25
age	Enterprise's age	138	15.8986	7.3527	2	32
loan	Enterprise's finance constraint	138	0.0968	0.1350	0.00	0.91
pro	Enterprise's profit rate	138	0.3233	0.3798	0.00	3.06

4. Empirical Results

4.1. Basic Results

Table 3 shows the estimated results of model (1). The control variables are gradually added in the regression process to test the robustness of the estimated results. Column (1) in Table 3 is the estimation result only considering the interaction term TradePUi15 × PostTrump16t. It can be found that the estimation coefficient of TradePUi15 × PostTrump16t is significantly negative. This indicates that enterprises with a higher export share have a greater decline in supply chain efficiency after 2016 than those with a lower export share. In other words, the rising uncertainty of trade policies reduces the supply chain efficiency of enterprises. This conclusion verifies hypothesis 1. Columns (2)–(5) show control variables that were gradually added to the regression equation, and it is found that the estimated coefficient of TradePUi15 × PostTrump16t is still significantly negative, indicating that the negative effect of the rising trade policy uncertainty on the supply chain efficiency of enterprises is still robust. The estimated results of control variables are basically consistent with most studies on enterprises' supply chains. An enterprise's scale has a significant negative impact on supply chain efficiency. That is, the larger the sales volume, the larger the inventory scale, and the lower the supply chain efficiency. There is a significant positive correlation between an enterprise's age and supply chain efficiency, indicating that the older an enterprise is, the higher its supply chain efficiency will be. The possible reason is that an earlier established enterprise has relatively mature production skills and management level, which is more conducive to improving its supply chain efficiency. Financing constraints

negatively affect the supply chain efficiency of enterprises, indicating that the greater the financing constraints, the higher the production cost of enterprises, which inhibits the improvement of supply chain efficiency. Enterprise's profit rate significantly promotes the improvement of supply chain efficiency, indicating that the stronger the enterprise's profitability, the higher the inventory management level, and the lower the inventory level [29], thus improving the supply chain efficiency.

Table 3. Basic results.

Variables	(1)	(2)	(3)	(4)	(5)
$TradePU_{i15} \times PostTrump16_t$	−0.0006 * (−1.52)	−0.0006 * (−1.48)	−0.0006 * (−1.47)	−0.0007 * (−1.90)	−0.0008 ** (−2.00)
scale		−0.0849 * (−0.58)	−0.0848 * (−0.57)	−0.1000 * (−0.69)	−0.2209 * (−1.37)
age			0.0063 * (0.00)	0.1074 * (0.36)	0.0460 * (0.15)
finance				−0.2162 ** (−2.13)	−0.1715 * (−1.64)
pro					0.1456 * (1.67)
cons	−0.4046 *** (−10.79)	0.0208 * (0.03)	0.0034 * (0.00)	0.9931 * (0.84)	1.2956 * (1.09)
firm-fixed effect	Yes	Yes	Yes	Yes	Yes
year-fixed effect	Yes	Yes	Yes	Yes	Yes
N	138	138	138	138	138
R^2	0.2104	0.3852	0.3852	0.4108	0.4264

Note: ***, **, and * indicate significance at 1%, 5% and 10% levels. *t* statistic values are reported in parentheses.

4.2. Robustness Checks

4.2.1. Other Measures of Supply Chain Efficiency

In the case of baseline regression, we adopt a three-stage Difference Exponential Average (DEA) model to measure supply chain efficiency. For the sake of robustness, we also adopt BBCO and CCRO methods to measure supply chain efficiency and then substitute them into model (1). The test results are shown in columns (1) and (2) of Table 4. It can be found that the estimation coefficient of the interaction term TradePUi15 × PostTrump16t and the coefficient sign and significance of other control variables have no significant changes, indicating that the impact of trade policy uncertainty on the efficiency of the enterprise's supply chain will not vary with the measurement methods of the explained variables.

Table 4. Robustness tests.

Variables	(1) Other Measurement Methods of Enterprise's Supply Chain Efficiency		(2) Economic Policy Uncertainty
	BBCO	CCRO	*EPU*
$TradePU_{i15} \times PostTrump16_t$	−0.0006 * (−1.68)	−0.0008 ** (−2.00)	
$EPU_{i15} \times PostTrump16_t$			−0.0004 ** (−2.00)
Control variables	Yes	Yes	Yes
cons	1.8261 * (1.77)	1.2956 * (1.09)	1.2956 * (1.09)
firm-fixed effect	Yes	Yes	Yes
year-fixed effect	Yes	Yes	Yes
N	138	138	138
R^2	0.3840	0.4264	0.4264

Note: ** and * indicate significance at 5% and 10% levels. *t* statistic values are reported in parentheses.

4.2.2. Alternative Measures of Trade Policy Uncertainty

For robustness, we use Economic Policy Uncertainty (EPU) index to measure TPU. EPUi15 is the EPU index of each firm in 2015, and trade policy uncertainty is expressed as EPUi15 × PostTrump16. It can be found that the estimation coefficient of the interaction term EPUi15 × PostTrump16t is still significantly negative, indicating again that the increase in trade policy uncertainty significantly reduces the efficiency of the enterprise's supply chain. This conclusion doesn't vary with the measurement methods of the core explanatory variables.

4.2.3. Other Ways

1. Anticipatory effect:

In order to ensure the effectiveness of DID estimation method, we first examine whether there is an expected effect in enterprises. Specifically, the time dummy variable of the year before 2016 is set as One year before and the time dummy variable of the yearbefore 2016 is set as Two year before, and a new interaction item is formed with TradePUi15 and added to the benchmark regression model (1) for testing. The results are listed in Table 5. It can be seen from columns (1) and (2) of Table 5 that the estimated coefficients of TradePUi15 × Oneyearbefore and TradePUi15 × Two year before of the two groups of interaction items are not significant, indicating that enterprises don't form expectations for further adjustment of supply chain efficiency before 2016.

2. Dynamic effect:

In order to compare annual differences, the dummy variable PostTrump16t in the benchmark regression model is replaced with Year τ, where τ is 2013, 2014, ..., and 2019. The expanded DID model is obtained:

$$EFF_{it} = \alpha_0 + \sum_{\tau=2013}^{2019} \beta_\tau TradePU_{i15} \times Year^\tau + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (2)$$

where $Year^\tau$ is the time dummy variable of each year, if τ is the year, the value is 1; otherwise, it is 0. It should be pointed out that 2012 is taken as the default comparison group here. The advantages of the empirical test of model (2) lie in that it can be used to test whether the changes in the supply chain efficiency of enterprises in the treatment group and control group can meet the linear homo-trend hypothesis before the policy impact and it can be used to explore the dynamic impact of trade policy uncertainty on the supply chain efficiency of enterprises. In particular, the former is an important identification hypothesis for the DID estimation test. Column (3) in Table 5 is the empirical test result of model (2). It can be found that the estimated coefficient of the interaction term in 2016 is negative but not significant. That is, the hypothesis of a co-trend is satisfied before the node of policy impact in 2016.

3. The policy impact node is 2017:

In order to ensure the robustness of DID estimation results, this paper adjusts the policy impact node to 2017. That is the year when variable $PostTrump16_t$ is 1 is set in 2017, and later. The estimated results are listed in column (4) of Table 5. It can be found that the estimated coefficient of the interaction term $TradePU_{i15} \times PostTrump16_t$ is still significantly negative, indicating again that the increase in trade policy uncertainty significantly reduces the efficiency of the enterprise's supply chain.

4. The sample interval is set from 2014 to 2018:

Since the sample interval of this paper is from 2007 to 2020, and the policy impact node is 2016, that is, compared with the post-policy, the time interval before the policy is relatively long, which may lead to inaccurate estimation results. For this reason, the sample interval in this paper is limited to two years before and after the occurrence of policy impact, that is, from 2014 to 2018. The estimated results are listed in column (5) of Table 5. It can

be found that compared with the baseline estimation results, although the absolute value of the estimated coefficient of the interaction term $TradePU_{i15} \times PostTrump16_t$ decreases somewhat, it is still significantly negative. It again supports the conclusion that the increase in trade policy uncertainty significantly reduces the efficiency of the enterprise's supply chain, indicating that the benchmark regression results are robust and reliable.

Table 5. Other ways.

Variables	(1) Anticipatory Effect	(2) Anticipatory Effect	(3) Dynamic Effect	(4) Policy Impact Node 2017	(5) Samples from 2014 to 2018
$TradePU_{i15} \times PostTrump16_t$	−0.0008 **	−0.0008 *		−0.0008 **	−0.0004 *
	(−1.98)	(−1.94)		(−2.03)	(−0.31)
$TradePU_{i15} \times Oneyearbefore$	0.0026	−0.0016			
	(0.45)	(−0.19)			
$TradePU_{i15} \times Twoyearbefore$		0.0045			
		(0.66)			
$TradePU_{i15} \times dummy2013$			−0.0042		
			(0.59)		
$TradePU_{i15} \times dummy2014$			−0.0054		
			(0.75)		
$TradePU_{i15} \times dummy2015$			−0.0037		
			(0.61)		
$TradePU_{i15} \times dummy2016$			−0.0040 *		
			(−0.54)		
$TradePU_{i15} \times dummy2017$			−0.0009 *		
			(−1.66)		
$TradePU_{i15} \times dummy2018$			−0.0014 *		
			(−1.37)		
$TradePU_{i15} \times dummy2019$			−0.0024 *		
			(−1.25)		
$TradePU_{i15} \times dummy2020$			−0.0007 *		
			(−1.42)		
Control variables	Yes	Yes	Yes	Yes	Yes
cons	−1.3332 *	−1.3297 *	−1.4283 *	−1.3042 *	−2.6947 *
	(−1.11)	(−1.11)	(−1.16)	(−1.09)	(−0.99)
firm-fixed effect	Yes	Yes	Yes	Yes	Yes
year-fixed effect	Yes	Yes	Yes	Yes	Yes
N	138	138	138	138	63
R^2	0.4267	0.4300	0.4399	0.4269	0.3631

Note: ** and * indicate significance at 5% and 10% levels. *t* statistic values are reported in parentheses.

5. How Does Trade Policy Uncertainty Affect the Efficiency of Enterprise's Supply Chain: A Test of Influencing Channels

5.1. Construction of Mediation Model

In order to clarify the internal channel mechanism of trade policy uncertainty affecting the efficiency of the enterprise's supply chain, we further construct the intermediary effect model for testing. Based on the above theoretical analysis, we select the enterprise's export value and technological innovation as intermediary variables to construct the following intermediary effect model:

$$Expansion_{it} = \alpha_0 + \alpha_1 TradePU_{i15} \times PostTrump16_t + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (3)$$

$$INN_{it} = b_0 + b_1 TradePU_{i15} \times PostTrump16_t + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (4)$$

$$EFF_{it} = c_0 + c_1 TradePU_{i15} \times PostTrump16_t + c_2 Expansion_{it} + c_3 INN_{it} + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (5)$$

$Expansion_{it}$ is the export quantity of the enterprise, which is expressed by the natural logarithm of the foreign trade cargo throughput. INN_{it} represents technological innovation, the proportion of intangible assets in total assets is used to describe the R&D behavior [30], and the natural logarithm is taken in regression.

5.2. Regression Results of Mediation Model

Table 6 reports the test results of the effect mechanism of trade policy uncertainty on the efficiency of enterprise's supply chain. Columns (1) and (2) correspond to the estimated results of model (3) and model (4), respectively. Columns (3) and (4) report the estimated results of the export value and technological innovation of the added enterprises, respectively. Column (5) reports the estimated results of the two intermediary variables added at the same time.

1. Checking the export quantity channel: Firstly, by observing the estimation results in column (1) of Table 6, it can be found that the estimation coefficient of the interaction term $TradePU_{i15} \times PostTrump16_t$ is significantly negative, indicating that the increase of TPU reduces the export quantity of enterprises. Secondly, the regression results in column (3) show that the estimated coefficient of intermediary variable *Expansion* is significantly positive, indicating that the increase in export quantity is conducive to improving the efficiency of the enterprise supply chain. Based on the above analysis, it can be seen that the mechanism of the increase of export quantity in TPU on the efficiency of the enterprise's supply chain is an intermediary effect, which means that the increase of TPU will reduce the efficiency of the enterprise's supply chain by reducing the export quantity, indicating that hypothesis 2 is valid: that is, the export quantity channel exists.
2. Examining technological innovation channels: Firstly, by observing the estimation results of column (2), it can be found that the estimation coefficient of the interaction term $TradePU_{i15} \times PostTrump16_t$ is significantly negative, indicating that the increase of TPU reduces the R&D investment of enterprises. Secondly, the regression results in column (4) show that the estimation coefficient of the intermediary variable *INN* is significantly positive, indicating that the increase in R&D investment is conducive to improving the efficiency of the enterprise's supply chain. Based on the above analysis, it can be seen that the mechanism of action of technological innovation in the increase of TPU on the efficiency of the enterprise's supply chain is shown as an intermediary effect, which means that the increase of TPU will reduce the efficiency of enterprise's supply chain by reducing the R&D investment of enterprises, indicating that hypothesis 3 is valid: that is, the technological innovation channel exists.
3. Examining export quantity channels and technological innovation channels: By observing the regression results in column (5), it can be found that the estimation coefficients of intermediary variables *Expansion* and *INN* are significantly positive, while the estimation coefficients of core explanatory variables, namely the interaction term $TradePU_{i15} \times PostTrump16_t$, are significantly negative. However, compared with the absolute value of the interaction item $TradePU_{i15} \times PostTrump16_t$ in column (5) of Table 3, the estimated coefficient decreased, indicating that the increase of TPU will affect the supply chain efficiency of enterprises through both export quantity and technological innovation channels, which also verifies hypothesis 2 and hypothesis 3.

The results of the above mechanism test fully show that the increase in trade policy uncertainty will reduce the supply chain efficiency of enterprises by reducing the export quantity and R&D input of enterprises. This conclusion means that there are two channels of export quantity and technological innovation when the uncertainty of trade policy increases in the process of affecting the efficiency of the enterprise's supply chain.

Table 6. Regression of mediation model.

Variables	(1) *Expansion*	(2) *INN*	(3) *EFF*	(4) *EFF*	(5) *EFF*
$TradePU_{i15} \times PostTrump16_t$	−0.0001 *	−0.0009 *	−0.00075 **	−0.0006 *	−0.0006 *
	(−0.15)	(−1.20)	(−1.99)	(−1.65)	(−1.64)
Expansion			0.3022 *		0.2880 *
			(1.05)		(1.08)
INN				0.2009 ***	0.2002 ***
				(4.15)	(4.13)
Control variables	Yes	Yes	Yes	Yes	Yes
cons	−8.5616 ***	−6.5644 ***	−1.2914 *	−2.6141 **	−0.1443 *
	(−2.01)	(−2.91)	(−0.47)	(−2.27)	(−0.06)
firm-fixed effect	Yes	Yes	Yes	Yes	Yes
year-fixed effect	Yes	Yes	Yes	Yes	Yes
N	138	138	138	138	138
R^2	0.9921	0.7983	0.4326	0.5091	0.5147

Note: ***, **, and * indicate significance at 1%, 5% and 10% levels. *t* statistic values are reported in parentheses.

6. Concluding Remarks

Based on the panel data of listed companies in the national port industry from 2007 to 2020 and on the basis of the theoretical analysis of the impact of trade policy uncertainty on supply chain efficiency, we take the China–US trade policy changes in 2016 as the entry point. We use the method of differential analysis and intermediary effect test to deeply explore the impact of trade policy uncertainty on the supply chain efficiency of enterprises. The conclusions are as follows: first, the increase in trade policy uncertainty can significantly reduce the efficiency of an enterprise's supply chain. Second, the conclusion is still robust after several robustness tests, such as replacing the explained variable and the explanatory variable and examining the expected effect and dynamic effect. Last, the results of the mechanism test show that the increase in trade policy uncertainty inhibits the improvement of the efficiency level of the enterprise's supply chain by reducing the export quantity and technological innovation.

This paper provides a new explanation for the dynamic changes in the supply chain efficiency of Chinese enterprises in recent years from the perspective of trade policy changes. The paper is also conducive to systematically evaluating the economic effects of trade policy uncertainty changes. Based on the conclusion of this paper, we try to put forward corresponding countermeasures and suggestions in the following aspects: First, the elimination of trade policy uncertainty is conducive to encouraging enterprises to strengthen research and development efforts and increase product exports, thus significantly improving the efficiency of enterprises' supply chain. Therefore, further promoting trade liberalization reform and eliminating trade policy uncertainty is of great practical significance for promoting enterprises' research and development, improving supply chain efficiency and export competitiveness. Although tariff rates of most of China's trading partners have been reduced to a relatively low level, various forms of non-tariff barriers still exist, and harsh anti-dumping against China frequently appears. The Chinese government should strengthen trade policy negotiations with these countries, further speed up the process of tax reduction and enhance the ability to deal with trade frictions. In addition, the Chinese government is committed to effectively reduce or even eliminate potential uncertainties in trade policies by signing free trade agreements and implementing the "One Belt, One Road" initiative, as well as actively participating in the formulation of international rules, so as to improve the supply chain efficiency and international competitiveness of Chinese enterprises, and steadily promote the construction of a trade power. Second, with the intensification of trade protectionism and the outbreak of the Russia–Ukraine war, the uncertainty of global trade policy continues to increase, and the harm brought by such external risks to enterprises is gradually increasing. Therefore, enterprises should pay attention to the changes in the international environment and improve their ability to deal

with trade frictions. In combination with its own characteristics, it should optimize internal resources and increase research and development efforts to improve its productivity, export competitiveness and supply chain efficiency, so as to enhance its defense capability in the international environment where the uncertainties of global trade policies continue to increase.

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