

The Impact of Enterprise Supply Chain Digitalization on Export Resilience

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Abstract. Cross-border trade has become increasingly volatile in the wake of tariff disputes and pandemic-related disruptions, which pushes firms to treat export resilience as a strategic priority rather than a routine performance metric. Although digitized supply chains are widely believed to support data-informed coordination and rapid response, rigorous evidence linking them to export resilience is still sparse. To fill this void, we construct a panel of China's A-share listed companies covering 2002-2023 and document a robust positive effect of supply chain digitalization on export resilience; the effect is especially strong for manufacturers, capital-intensive sectors, and firms in their expansion phase. The results offer actionable evidence for corporate strategy and useful levers for policymakers.

Keywords: supply chain digitalization, export resilience, firm heterogeneity

1. Introduction

1.1. Background

Trade activity worldwide has been clouded by rising uncertainty since the post-2018 tariff disputes and the COVID-19 pandemic, which together slowed global growth and ate into trade demand. China, anchored at the core of global value chains, was hit particularly hard: National Bureau of Statistics figures show that the country's annual export growth collapsed from roughly 20% in 2007 to -16% in 2009.

Such fluctuations have prompted all fields to think a fundamental question: what exactly should enterprises do to better withstand external shocks and recover their export capabilities [1, 2]? A review of literature on supply chains shows that digitalization is almost universally regarded as a critical strategy for survival and recovery during crises [3]. So, based on this academic background, our article will explore a specific question: does digitalization of the supply chain can actually make a company more resilient when it comes to exports?

Imagine when you bring digital tools into the process of sourcing, production, storage, and shipping, the whole supply chain will become a single, connected system that you can manage in real time. If something goes wrong, you will notice it right away and fix it quickly [4]. From the perspective of dynamic capabilities [5, 6], this kind of digital framework give two big things: it sharpens your radar for changes in the outside world, and helps you feel fast, seizing new chances and adapting your resources. That's exactly the kind of muscle you need when the ground keeps

shifting under your feet. Now, many researchers have already shown that digitalization can boost your edge through better efficiency, lower transaction costs, and smarter resource use [7, 8]. But here's the problem, almost no one has actually tested whether digitalization of the entire supply chain has a direct line to export resilience. And that, to us, is the gap worth digging into.

To bridge this gap, we exploit variation across China's A-share listed firms from 2002 to 2023, proxy digitalization with the count of digital-transformation keywords disclosed in annual reports, and operationalize export resilience as the gap between current export performance and the 2009 post-crisis benchmark. Baseline regressions, an instrumental-variable strategy (2SLS) that mitigates endogeneity, and a battery of robustness tests consistently point to the same conclusion: supply chain digitalization materially improves firm-level export resilience.

Despite a rich literature on how digital transformation lifts firm performance, the dominant strand of work still looks inward, focusing on productivity, cost, or innovation inside the firm, and largely ignores the network externality of digitalization along the supply chain [9, 10]. In practice, firms do not export in isolation: the digital maturity of their upstream suppliers and downstream customers shapes their own export outcomes [11, 12]. How supply-chain digitalization feeds into export resilience, whether by tightening the match between supply and demand, by anchoring more stable partnerships, or by making joint innovation easier, remains an open question.

Additionally, most existing empirical evidence still comes from Western economies, whether this logic applies to transition economies, especially to Chinese manufacturing enterprises, has not been seriously examined [2]. In order to fill in those blanks, we turn to data from China's A-share listed companies and run a three-dimensional heterogeneity test, breaking things down by industry type, factor intensity, and lifecycle stage. Sure, other studies might have touched on one or two of these angles before, but they always put them in isolation. Hardly anyone has thrown all three into the same pot and stirred them together.

Compared to earlier work, our paper brings three fresh things to the table. First, we go straight for the result: we ask whether supply-chain digitization actually moves the needle on a firm's export performance. That's new for this field, because most previous research has been stuck on big-picture stuff, including exchange rates, consumer demand, policy shifts, and so on. By checking whether digital integration up and down the industrial chain can create a real synergy, we're handing over solid empirical evidence. Plus, this directly tackles the blind spot that Vial [13] pointed out: namely, how tech changes the way firms interact with each other. Second, our empirical work doesn't just lump everything together. We divide the sample into different types of industry resource dependency, and company age. Our results show that the resilience-boosting effect of digitization only really shows up in manufacturing firms, asset-heavy players, and companies that are in their fast-growth phase. Third, our findings are actually useful for policymakers. They give a much clearer picture of which companies can genuinely turn digital tech into an export edge, and that's exactly what Li et al. [2] called for, stressing that we can't study automation's impact on export flexibility without considering firm-specific traits.

2. Research hypothesis

2.1. Supply chain digitalization and enterprise export resilience

A growing body of work treats supply-chain digitalization and firms' overseas operations, particularly outward foreign direct investment (OFDI), as closely intertwined drivers of export resilience. On one hand, digitizing the supply chain improves information flow, compresses transaction costs, and sharpens resource allocation, all of which make international expansion more

viable [14]. On the other hand, OFDI feeds back into export resilience through reverse technology spillovers, market diversification, and reconfigured supply networks [15].

What the existing literature leaves unclear, however, is whether digitalization per se moves export resilience directly, or only does so indirectly via overseas operations.

We therefore step outside the conventional "digitalization → overseas operations → resilience" pipeline and ask whether supply-chain digitalization has its own first

order effect on resilience. Building on Su et al.'s [14] framework, in which digital transformation lifts total factor productivity, dilutes asset specificity, and disperses supply-chain concentration, thereby easing overseas expansion, and on Li et al.'s [15] model of how FDI transmits to export resilience through vertical industrial linkages, we propose a direct theoretical channel from supply-chain digitalization to export resilience. The channel also carries clear policy relevance, as it points to a tangible lever for strengthening firms' ability to weather trade risks in a volatile environment. We therefore hypothesize:

H1 Supply chain digitalization significantly enhances enterprise export resilience.

2.2. Supply chain digitalization, enterprise export resilience and other factors

At the same time, Tao et al. [12] find that the backward spillover effect of digital transformation is stronger in manufacturing firms, likely because this sector demands greater supply chain coordination and efficiency gains.

Zhang and Duan [16] show that digital empowerment has a more pronounced effect on non-high-tech enterprises. What this suggests is that companies with a weaker tech foundation actually seem to get more benefits for their buck from digitalization.

On the side, Cai et al. [17] look at things through the lens of supply-chain spillovers and argue that tax-cut incentives don't drive digital transformation in a one-size-fits-all way, instead, their effect changes depending on which stage of the lifecycle a firm happens to be in. Put these two viewpoints side by side, and a clear picture emerges: the impact of supply-chain digitization on export resilience isn't set in stone. Instead, it bends and twists depending on what type of company you're looking at and where it stands in its own growth process. That line of thinking leads us to our next hypothesis:

H2 The effect of supply-chain digitalization on a firm's export resilience varies significantly across different groups, manufacturing vs. non-manufacturing, industries with different traits, and companies at different lifecycle stages.

3. Research design

3.1. Sample selection and data source

Our working sample covers all firms listed on China's A-share market between 2002 and 2023. We apply three filters: (i) drop companies under special treatment (ST and *ST); (ii) remove observations whose core financial fields are materially incomplete; and (iii) fill in remaining isolated gaps via interpolation. After filtering, 5,939 firm-year observations remain. Digitalization variables are drawn from the CSMAR database, and export-resilience measures are constructed using the China Urban Statistical Yearbook. Firm life-cycle stage, industry affiliation, and financial controls are pieced together from annual reports, CSR reports, corporate websites, and the websites of China's environmental regulators, all harvested with data-mining tools.

3.2. Variable selection and measurement

3.2.1. Dependent variable: export resilience of enterprises

Following Zhao et al. [18], we treat the 2008–2009 financial crisis as a quasi-exogenous shock and use it as the reference point for measuring export resilience. The underlying idea is that the further a firm's export performance climbs above its post-crisis trough, the smaller the lasting damage from the shock and the greater its inherent resilience. Operationally, we collect firm i 's export value in year t , in 2008, and in 2009, and construct the resilience index as:

$$\text{Export Resilience}_{i,t} = \frac{\text{Export}_{i,t} - \text{Export}_{i,2009}}{\text{Export}_{i,2008}} \quad (1)$$

Larger values of the index indicate stronger recovery from the crisis low and, therefore, higher export resilience.

3.2.2. Independent variable: digitalization of supply chain of enterprises

For manufacturing firms, digitalization has emerged as a central route toward high-quality growth. Following Zhao et al. [8], we mine corporate annual reports with Python for a curated set of digitaltransformation keywords and use $\ln(1 + \text{keyword count})$ as our digitalization intensity measure.

3.2.3. Control variables

Eight control variables are constructed from CSMAR and corporate annual reports: return on assets (ROA), leverage (Lev), firm size (Size), CEO-board chair duality (Dual), board independence (Indep), board size (Board), firm age (FirmAge), and cash-flow strength (CashFlow). Firm and year fixed effects are included throughout.

3.3. Econometric model specification

To empirically test the impact of digitalization on export resilience, this study constructs the following benchmark econometric model. In this setup, export resilience is the dependent variable, and "the digitalization intensity (Dig) serves as the focal regressor. To isolate the effect of digitalization, we include a set of control variables that capture other factors potentially affecting a region's or firm's capacity to withstand and recover from external shocks. The model also incorporates year fixed effects (μ_t) to sweep out unobserved, timeinvariant differences across industries, as well as industry fixed effects (η_j) to account for time-invariant heterogeneity across industries. The error term is denoted by $\varepsilon_{i,t}$. The full regression specification is as follows:

$$\text{Export Resilience}_{i,t} = \beta_0 + \beta_1 \text{Dig}_{i,t} + \sum_k \gamma_k \text{Controls}_{i,t}^k + \mu_i + \eta_t + \varepsilon_{i,t} \quad (2)$$

4. Benchmark result

4.1. Descriptive statistics

Descriptive statistics are summarized in Table 1. The Export Resilience index averages 10.649 SD = 57.797 , with a range from−0.999 to 1,282.171; the wide dispersion reflects substantial

heterogeneity in how firms recovered from the 2008–2009 shock. The digitalization intensity (Dig) has a mean of 0.0383 and an SD of 0.083, with realized values between 0 and 1.071.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std.	Min	Max
Export resilience	5,923	10.649	57.797	-.999	1282.171
Dig	5,923	0.0383	0.083	0	1.071
ROA	5,923	0.033	0.057	-.556	0.222
Lev	5,923	0.454	0.207	0.0278	0.908
Size	5,923	22.486	1.45	19.435	26.452
Dual	5,923	0.209	0.406	0	1
Indep	5,923	0.375	0.056	0.25	0.6
Board	5,923	2.155	0.201	1.61	2.708
FirmAge	5,923	2.867	0.387	0.693	3.689
CashFlow	5,923	0.044	0.0639	-.222	.282

4.2. Benchmark regression results

Columns (1)–(2) of Table 2 report the baseline estimates. The coefficient on supply-chain digitalization is positive and significant at the 1% level in both specifications—whether or not controls and fixed effects are included—indicating that digitalizing the supply chain meaningfully strengthens firm-level export resilience. H1 is therefore supported.

Table 2. Benchmark regression results

	(1) Export resilience	(2) Export resilience
Dig	39.0608*** (2.6786)	37.6926*** (2.6437)
Constant	36.0104*** (4.1640)	-53.1026** (-2.4911)
Controls	NO	Yes
Year fe	Yes	Yes
Industry fe	Yes	Yes
Observation	5923	5923
R-squared	0.0390	0.0543

4.3. Endogeneity analysis

To deal with endogeneity from omitted variables and reverse causality, we estimate a 2SLS instrumental-variable model. The firststage diagnostics in Table 3 column (1) comfortably clear

conventional benchmarks: the Kleibergen-Paap LM statistic rejects the underidentification null, and the Kleibergen-Paap Wald F-statistic of 5.4817 lies above the weak-identification threshold. In the second stage (Table 3 column 2), the Dig coefficient remains positive and statistically significant $\beta = 440.0606, p < 0.01$ after instrumenting. The headline conclusion is therefore robust to endogeneity correction, in line with H1.

Table 3. Endogeneity analysis results

	(1) Dig	(2) Export resilience
Dig-Provincial Average	0.4228*** (5.4817)	
Dig		440.0606** (2.3529)
Controls	Yes	Yes
Constant	-0.0066 (-0.2436)	-51.3735** (-1.9805)
Year fe	Yes	Yes
Industry fe	Yes	Yes
Observation	5923	5923
r2_a	0.1698	-0.2245

4.4. Robustness tests

4.4.1. Core variable substitution

In our first robustness check—shown in Table 4, column (1)—we change the original independent variable into a different one: the natural log of the supply-chain digitization keyword count, which we call *ln_{ds}* ($ln_{ds} = \ln(\text{Supply Chain Digitalization Word Frequency})$). The coefficient on export resilience came in at 5.7729, and it's significant at the 1% level. This shows even when we changed how we measured digitalization, the positive link didn't change. That tells us our main result isn't a fluke—there's a solid, durable positive relationship between export resilience and supply-chain digital transformation.

4.4.2. One-period lag

For our second robustness check, we take the supply chain digitization variable and pushed it back by one period, giving it a one-year lag. The coefficient we get for export resilience was 49.0973, still positive and still significant at the 1% level. And there is the reliable part, whether you look at the direction of the effect, its statistical significance, or the sheer magnitude of the coefficient, everything matches almost perfectly with our baseline regression. That gives us a good deal of confidence that our main model isn't fragile—it holds steady under this alternative setup.

4.4.3. Time period adjustment--recent decade

To exclude the influence of external shocks, the study conducts robustness tests over a ten-year period. In Robustness tests(3), the regression coefficient for corporate export resilience on supply chain digitalization is 39.1549, significant at the 5% level. This consistency between coefficient sign and significance confirms the study's reliability and stability, which is unaffected by the sample time period.

Table 4. Robustness tests

	(1) Export resilience	(2) Export resilience	(3) Export resilience
lnds	5.7729*** (2.9301)		
L.Dig		49.0973*** (2.7440)	
Dig			39.1549** (2.0848)
Controls	Yes	Yes	Yes
Constant	-85.9011** (-2.4501)	-43.1795* (-1.8726)	-63.0441 (-1.6090)
Year fe	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes
observation	3110	5699	3286
r2_a	0.0562	0.0533	0.0609

5. Heterogeneity analysis

5.1. Manufacturing industry

Not all industries are created equal when it comes to the payoff from supply-chain digitalization. There is the truth that Chinese manufacturing firms, which tend to have a stronger tech base and much more complex supply-chain webs, the resilience gains from going digital are significantly larger than other industries. To exam this heterogeneity, we divide our sample into two buckets: manufacturing and non-manufacturing. The results shows in Table 5, supply-chain digitalization delivers a clearly positive and significant punch to export resilience in the manufacturing camp, while in other industries, we just don't see any comparable effect.

Table 5. Heterogeneity analysis 1

	(1) Export resilience	(2) Export resilience
Dig	26.3106	42.6286**

Table 5. (continued)

	(1.1767)	(2.4768)
Controls	Yes	Yes
Constant	-82.1051	-66.1037***
	(-0.9510)	(-3.4540)
Year fe	Yes	Yes
Industry fe	Yes	Yes
Is it manufacturing	No	Yes
observation	1215	4708
r2_a	0.0379	0.0563

5.2. Technology intensive classification

How well supply-chain digitization pays off really influences on factor intensity. In labor-heavy sectors like textiles, weak digital roots mean slower gains, while in tech-heavy ones like steel, digital tools fit right in and deliver faster. Capital-heavy utilities benefit mainly from cost and efficiency wins. So outcomes and timing vary widely. Consistent with this view, the column (2) estimates in Table 6 indicate that digitalization lifts export resilience in both laborintensive and capital-intensive industries.

Table 6. Heterogeneity analysis 2

	(1)		(2)		(3)
	Labor-intensive	vs	Technical-intensive	vs	Asset-intensive
	Export resilience		Export resilience		Export resilience
Dig	12.1717		-3.6941		661.6183**
	(1.2010)		(-0.4910)		(2.4853)
Controls	Yes		Yes		Yes
Constant	-1.7e+02**		-27.9670		-88.8134**
	(-2.4909)		(-1.4567)		(-1.9681)
Year fe	Yes		Yes		Yes
Industry fe	Yes		Yes		Yes
Observation	1564		3084		1253
r2_a	0.0440		0.1073		0.1158

5.3. Life cycle

The payoff from supply-chain digitalization is also likely to depend on where a firm stands in its life cycle, with growth-stage firms plausibly reaping the largest resilience gains because their organizational flexibility still outpaces their digital sunk cost. We test this proposition by splitting

the sample by life-cycle stage. As Table 7 shows, the digitalization-resilience link is positive and economically large for growth-stage firms, while it is statistically indistinguishable from zero in the maturity and decline stages

Table 7. Heterogeneity analysis 3

	(1)		(2)		(3)
	Growth period	vs	Maturation period	vs	Decline period
	Export resilience		Export resilience		Export resilience
Dig	123.4190***		10.7054		-13.4815
	(2.8434)		(0.8793)		(-1.3729)
Controls	Yes		Yes		Yes
Constant	2.4791		-39.3535		-82.8819**
	(0.0580)		(-1.0701)		(-2.1202)
Year fe	Yes		Yes		Yes
Industry fe	Yes		Yes		Yes
Obeservation	2113		1986		1643
r2_a	0.0570		0.0737		0.1135

6. Research conclusions

This study conducts a theoretical analysis of how supply chain digitization affects export resilience, then use data to verify the underlying mechanism. Finally, we draw two conclusions: First, supply chain digitization can indeed significantly improve firms' export resilience. Second, this positive effect is not universally applicable, instead, it manifests particularly prominently among manufacturing firms, heavy-asset enterprises, and companies in their growth phase. In other words, firms with stronger foundational resources or those currently undergoing rapid expansion are better positioned to benefit from this wave of digital transformation.

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