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DIGITAL CONNECTIVITY, ECONOMIC COMPLEXITY AND THE SHOCK SPECIFICITY OF EXPORT RESILIENCE

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ABSTRACT

Whether broad structural capabilities make national exports resilient across qualitatively different global crises remains uncertain. This study compares export resistance during the 2008–2009 global financial crisis and the 2020 pandemic across a broad international sample using annual real merchandise export volume. Resistance is measured as the gap between realized log export volume in the shock year and a no-shock benchmark extrapolated from each country's preceding export trend. Pre-shock internet use measures digital connectivity and the economic complexity index captures productive capabilities. Cross-sectional regressions assess their individual and joint associations while controlling for income, population, trade openness, and region. The results show no robust resilience premium from internet connectivity, economic complexity, or their interaction across both shocks. Among 139 economies observed in both episodes, export-resistance rankings are only weakly related, with a Pearson correlation of 0.141 and a Spearman correlation of 0.059. Excluding 2008 from the financial-crisis counterfactual leaves this conclusion unchanged. Simple structural models also have limited predictive content within each crisis and do not improve when transported across crises. The evidence therefore supports a shock-contingent interpretation of aggregate export resilience and cautions against treating broad national indicators as universal buffers.

Keywords: Export Resilience, Digital Connectivity, Economic Complexity, Global Shocks, International Trade

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1. Introduction

The same economy can be resilient to one global crisis and fragile to another. This possibility is easy to state but is often obscured in empirical work that studies a single shock and then interprets the estimated correlates of resilience as broadly protective characteristics. The problem matters for international trade because the channels that disrupt exports are not constant across crises. The 2008-2009 global financial crisis was dominated by a collapse in expenditure, trade-intensive durable demand, inventory adjustment, and constraints in trade finance. The 2020 pandemic combined demand weakness with factory closures, mobility restrictions, disruptions to global production networks, and an abrupt premium on activities that could be coordinated at a distance (Bems et al., 2013; Bonadio et al., 2021; Espitia et al., 2022). A capability that cushions one of these mechanisms may do little against the other.

Two structural characteristics are especially plausible candidates for a broad resilience role. The first is digital connectivity. Digital technologies can reduce information and coordination costs, facilitate remote work, support communication with customers and suppliers, and help firms reorganize activities when physical interaction becomes difficult. Firm-level evidence is generally supportive. Copestake et al. (2024) show that firms in more digitalized industries experience smaller revenue losses during recessions, with especially strong effects during the pandemic. Constantinescu et al. (2026) find that better digital infrastructure strengthens firm resilience where work can be performed remotely. Li et al. (2024) report that digital transformation increased export resilience among Chinese firms following the global financial crisis. These findings provide a strong reason to ask whether broad national internet connectivity also translates into more resilient aggregate exports.

The second candidate is economic complexity. The economic complexity framework treats the products a country can competitively export as an observable reflection of the productive knowledge and capabilities embedded in its economy (Hidalgo & Hausmann, 2009). Countries with more complex productive structures may have a broader capability base from which to adapt production, reallocate resources, and respond to disruptions. Yet complexity does not guarantee insulation from shocks. Nguyen and Schinckus (2023) show that economic complexity can reduce some dimensions of macroeconomic volatility while also being associated with greater sensitivity to certain external shocks. Bas et al. (2024) likewise demonstrate that product characteristics mediate trade responses differently across stages of the pandemic. The direction and stability of the relationship are therefore empirical questions rather than assumptions.

This study examines whether internet connectivity and economic complexity act as stable correlates of national export resistance across two structurally different global shocks. It compares the global financial crisis and the pandemic using the same outcome construction, the same pre-shock measurement logic, and a largely common country sample. Real merchandise export volume is used rather than nominal export value so that price movements do not mechanically drive the resilience measure. For each crisis, the main outcome is the deviation of realized log export volume from a country-specific no-shock benchmark extrapolated from the preceding four-year export trend. Hara and Yamamoto (2026) develop a

formal counterfactual framework for real gross domestic product resilience in 18 advanced OECD economies. The present analysis asks a different external-validity question. It tests whether structural predictors of real merchandise export resistance retain predictive content across crises in a much broader global sample.

The analysis makes three contributions. First, it shifts the cross-crisis resilience question from aggregate output in a small advanced-economy sample to real merchandise exports across roughly 140 economies. This matters because trade is a direct transmission margin for global disturbances and because export exposure varies sharply across development levels and production structures. Second, it evaluates two widely discussed structural characteristics, internet connectivity and economic complexity, without assuming that either must provide a universal resilience premium. Third, it tests portability directly. In addition to shock-specific regressions, the study compares country rankings in export resistance across crises and asks whether a model estimated in one episode has useful predictive content in the other. The contribution is therefore not a new generic claim that resilience is shock-specific, but a trade-specific test of whether commonly invoked structural predictors travel across fundamentally different global disruptions.

The results are more cautionary than a simple resilience-premium narrative would suggest. Internet connectivity, economic complexity, and their interaction do not display robust and stable associations with export resistance across both crises. Among 139 economies observed in both episodes, the Pearson correlation between the two resistance measures is only 0.141 and the Spearman rank correlation is 0.059. Countries that performed relatively well during the global financial crisis were therefore not systematically the same countries that performed relatively well during the pandemic. A stricter financial-crisis benchmark that excludes 2008 from the pre-crisis trend leaves this conclusion unchanged. Simple structural models also show limited predictive content within each episode and perform poorly when transported across crises. Across these two major disruptions, the evidence is more consistent with shock-contingent export resilience than with a fixed national resilience profile.

This conclusion does not imply that digitalization or productive capabilities are unimportant. It instead narrows the claim that can be supported at the country level. Digital tools can clearly help particular firms and sectors adapt to specific disruptions. Complex productive structures can expand the range of feasible responses. What the evidence does not support is the stronger proposition that population-level internet connectivity and economic complexity provide a stable aggregate export premium across these two qualitatively different global crises. That distinction matters for policy because preparedness based on a short list of generic indicators can create false confidence when the relevant transmission mechanism changes.

The remainder of the article proceeds as follows. Section 2 reviews the literature on economic resilience, digitalization, economic complexity, and shock-specific trade adjustment. Section 3 describes the data, the construction of the export-resistance measure, and the empirical strategy. Section 4 presents the findings, including cross-shock persistence and portability tests. Section 5 discusses the implications and limitations. Section 6 concludes.

2. Literature Review

2.1 Economic Resilience and Shock Specificity

Economic resilience is commonly understood as the capacity of an economy to withstand, absorb, adapt to, or recover from adverse disturbances. Rose (2004) emphasizes the distinction between vulnerability to a shock and the capacity to limit losses once the shock occurs. Briguglio et al. (2009) similarly distinguish structural exposure from resilience capacities that help an economy withstand or recover from exogenous disturbances. In regional economics, Martin (2012) and Martin and Sunley (2015) argue that resilience is not a single outcome. Resistance to the initial downturn, the speed and character of recovery, and possible changes in the post-shock growth path are conceptually distinct dimensions.

That distinction is particularly important in global crises. When almost all economies are affected at the same time, conventional comparisons with untreated countries become difficult. Hara and Yamamoto (2026) address this problem by constructing no-crisis trajectories from pre-crisis data and evaluating realized performance against those benchmarks. Their comparison of the global financial crisis and the pandemic shows that the depth of the initial shock and the subsequent recovery can differ markedly across episodes. More broadly, the World Trade Organization (2021) stresses that trade can transmit shocks but can also support adjustment through access to alternative suppliers, markets, and essential goods.

The global financial crisis and the pandemic illustrate why resilience may not be portable. The trade collapse of 2008-2009 reflected a sharp contraction in global expenditure that was concentrated in durable and trade-intensive goods, amplified by inventory adjustment and financing constraints (Bems et al., 2013). The pandemic added a different set of restrictions. Lockdowns, workplace closures, travel constraints, and disruptions in production networks directly affected the feasibility of producing and coordinating economic activity. Bonadio et al. (2021) show that international production networks transmitted pandemic shocks but also allowed foreign inputs to cushion domestic disruptions in some cases. Espitia et al. (2022) find that sectors more amenable to remote work contracted less, while global value-chain participation could either amplify foreign shocks or reduce exposure to domestic shocks.

These differences imply that a country characteristic should not be called a general resilience factor merely because it predicts outcomes in one episode. A stronger test is whether its association survives across shocks with different transmission mechanisms. The present study adopts that cross-shock criterion.

2.2 Digital Connectivity and Export Resilience

The case for digital connectivity rests on several mechanisms. Digital connectivity can lower search and communication costs, allow firms to interact with customers and suppliers without physical proximity, support remote work, and facilitate rapid reorganization of administrative and commercial processes. These channels are likely to be especially valuable when mobility and face-to-face interaction are constrained. The pandemic therefore provides a setting in which pre-existing connectivity should have had unusually high potential value.

Existing microeconomic evidence supports this view. Copestake et al. (2024), using firm-level data from 75 countries, find that firms in more digitalized industries suffer smaller revenue losses during recessions and that the relationship is especially strong during the pandemic. Constantinescu et al. (2026), using business survey data from 61 countries, show that firms in sectors more suitable for remote work experienced smaller pandemic losses in countries with stronger digital infrastructure. Their results also indicate an exporting premium in manufacturing. Espitia et al. (2022) similarly find that sectors with greater remote-work feasibility experienced smaller trade contractions during the early pandemic.

Evidence focused directly on exporting firms also points toward a protective role. Li et al. (2024) show that digital transformation enhanced export resilience among Chinese listed firms after the 2008 financial crisis. These studies are valuable but do not establish that aggregate national internet connectivity has a stable effect across crises. Firm-level digital capability, sectoral remote-work feasibility, and population-level internet use capture different concepts. Aggregation can also wash out firm-level advantages if digitally intensive firms are concentrated in sectors that face stronger global demand shocks.

This study therefore uses internet use as a deliberately broad and comparable pre-shock measure of digital connectivity. It is not intended to represent the full multidimensional concept of digital readiness. Its value is cross-period comparability and wide country coverage. The empirical question is whether countries entering a crisis with a larger share of internet users show systematically smaller deviations from their own pre-crisis export path.

2.3 Economic Complexity and Productive Capabilities

Economic complexity offers a complementary perspective on resilience. Hidalgo and Hausmann (2009) interpret the diversity and sophistication of a country's export basket as an indirect measure of the productive capabilities available in the economy. A complex economy is capable of producing and exporting goods that few other countries can make and that require combinations of specialized knowledge. This capability base could support adaptation when particular products, inputs, or markets are disrupted.

The resilience implication is not mechanically positive, however. Complex economies are often deeply integrated into international production networks. That integration can create diversification opportunities but can also expose production to disruptions transmitted through foreign demand and imported inputs. Nguyen and Schinckus (2023) find that economic complexity is associated with lower growth volatility in some specifications but can increase vulnerability to external shocks under others. Bas et al. (2024) show at the product level that lower complexity was associated with larger pandemic export losses in some stages, while the roles of product characteristics changed as the crisis evolved. These findings suggest that complexity can interact with the type and timing of the shock.

A natural extension is to ask whether internet connectivity and economic complexity are complementary. Connectivity may be more valuable when firms can use it to coordinate a diverse set of sophisticated activities, while complex productive capabilities may be easier to redeploy when information and communication frictions are low. These mechanisms motivate a positive interaction hypothesis. At the same time, the strength of the association may be

crisis-specific because digital coordination is particularly relevant to shocks that restrict physical interaction, while the global financial crisis operated more strongly through expenditure and finance. Cross-shock stability is therefore evaluated separately from the directional hypotheses.

2.4 Hypotheses and Cross-Shock Portability

The literature motivates three directional hypotheses for shock-specific export resistance.

H1. Higher pre-shock internet connectivity is associated with greater export resistance.

H2. Higher pre-shock economic complexity is associated with greater export resistance.

H3. Economic complexity strengthens the positive association between pre-shock internet connectivity and export resistance.

The hypotheses concern associations within a given shock. The study then applies a more demanding cross-shock test by asking whether the signs, magnitudes, country rankings, and predictive content implied by these relationships are stable between the global financial crisis and the pandemic. Because the two crises operated through different transmission mechanisms, cross-shock portability is treated as an empirical question rather than imposed as a directional hypothesis.

3. Method

3.1 Data and Sample

The analysis combines annual country-level data from the World Development Indicators and the Atlas of Economic Complexity. The outcome is the World Bank export volume index with 2015 equal to 100. The series originates from the United Nations Conference on Trade and Development and measures changes in the physical volume of merchandise exports after adjusting for price effects. Using a volume measure is important because nominal export values during 2008-2009 and 2020 were affected by large movements in commodity prices, exchange rates, and unit values that do not necessarily represent changes in exported quantities.

Annual frequency is used to preserve a common, price-adjusted merchandise export-volume measure and a consistent country sample across both crises. The same frequency also aligns naturally with the pre-shock internet-use, economic-complexity, and macroeconomic covariates used in the design. A monthly or quarterly trade series would describe the timing of collapse and rebound more precisely, but it would change the outcome construction and weaken the broad historical comparability that is central to the two-shock design. The choice therefore prioritizes cross-country and cross-crisis consistency over within-year timing. Accordingly, the dependent variable should be interpreted as net annual shock-year resistance, not as a measure of the exact timing of the trough or the speed of recovery. This trade-off is considered explicitly in Section 5.

Digital connectivity is proxied by individuals using the internet as a percentage of the population. The underlying indicator is produced by the International Telecommunication

Union and distributed through the World Development Indicators. Internet use is defined as the share of individuals who used the internet from any location during the preceding three months. A broader measure based on fixed broadband subscriptions is feasible for the pandemic period but not for the pre-financial-crisis period without a substantial loss of historical comparability. Internet use is therefore the main cross-shock measure, while fixed broadband is used in a pandemic-only sensitivity check reported in Table 6.

The internet-use indicator is not converted into a firm-level measure in the present analysis. The unit of observation is the country, so the variable is interpreted as the economy-wide connectivity environment in which exporters operate rather than as a measure of firm digital transformation. Firm-level studies motivate the mechanisms discussed in Section 2, but exporter adoption of cloud services, enterprise software, e-commerce, digital supply-chain systems, cybersecurity tools, or remote-work practices may vary substantially within a country. A firm-level adaptation of this framework would replace population internet penetration with exporter-specific adoption measures and combine them with firm and sector controls. The country-level coefficient reported here should therefore be read as an association with national connectivity, not as an estimate of the return to firm-level digitalization or of the causal effect of expanding general internet penetration.

Economic complexity is measured with the Economic Complexity Index from the Growth Projections and Complexity Rankings dataset of the Atlas of Economic Complexity. The primary measure uses the Harmonized System 1992 classification. The index captures information about the diversity and sophistication of a country's productive capabilities as revealed by its export structure. A Standard International Trade Classification version is used as a sensitivity measure and is reported in Table 6.

For the main global financial crisis specification, pre-shock covariates are averaged over 2006-2008. For the pandemic, they are averaged over 2017-2019. At least two nonmissing annual observations are required to form each pre-shock average. The control set includes gross domestic product per capita at purchasing power parity in constant 2021 international dollars, total population, and trade as a percentage of gross domestic product. Gross domestic product per capita and population enter in logarithms. All continuous regressors are standardized within each shock sample before estimation. Because the global financial crisis intensified during 2008, a stricter sensitivity specification excludes 2008 from both the financial-crisis counterfactual trend and the covariate averages, using 2005-2007 instead. This specification is reported in Table 6.

The baseline sample contains 142 economies for the global financial crisis and 140 for the pandemic. There are 139 economies observed in both episodes. Specifications that include the full set of controls and region indicators use 129 and 130 economies because of missing pre-shock control data. Aggregated regions and income groups are not treated as countries.

Table 1. Variable definitions and data sources

Variable	Definition	Source
Export resistance	Log shock-year export volume minus the value predicted from the preceding four-year country-specific trend	World Development Indicators / UNCTAD
Internet use	Mean share of individuals using the internet in 2006-2008 or 2017-2019	ITU via World Development Indicators

Economic complexity	Mean HS92 Economic Complexity Index in the corresponding pre-shock window	Atlas of Economic Complexity
GDP per capita	Mean GDP per capita at PPP in constant 2021 international dollars, entered in logs	World Development Indicators
Population	Mean total population, entered in logs	World Development Indicators
Trade openness	Mean exports plus imports of goods and services as a percentage of GDP	World Development Indicators

3.2 Measuring Export Resistance

The main outcome is resistance to the initial export shock. Let x_{it} denote the natural logarithm of the real merchandise export volume index for country i in year t. For each crisis, a country-specific linear trend is estimated using the four years immediately preceding the shock year. The main global financial crisis specification uses 2005-2008 to predict 2009, while the pandemic specification uses 2016-2019 to predict 2020. Because the global trade contraction had begun by late 2008, the analysis also reports a stricter financial-crisis sensitivity measure that estimates the trend only over 2005-2007 and therefore does not use 2008 to construct the counterfactual.

The pre-shock model for each country is written as

$$x_{it} = a_i + b_i t + u_{it} \quad (1)$$

and is estimated only on pre-shock observations. The no-shock benchmark for the crisis year s is then obtained from the fitted trend. Export resistance is defined as

$$R_{is} = x_{is} - \hat{x}_{is}(no\ shock) \quad (2)$$

A value of zero indicates that realized export volume in the shock year was exactly on its extrapolated pre-shock path. A negative value indicates an export shortfall relative to that path, while a positive value indicates performance above the extrapolated benchmark. The measure should be interpreted as a descriptive counterfactual rather than a causal treatment effect. It does not claim that the pre-shock linear trend would have continued exactly in the absence of the crisis. Its purpose is to provide a common, scale-free benchmark that adjusts for each country's recent trajectory and avoids reliance on an unaffected control group.

The choice is consistent with the broader resilience literature that evaluates post-shock performance relative to a pre-crisis path (Martin, 2012; Hara & Yamamoto, 2026). Robustness checks use alternative outcome definitions and measurement choices. These include a three-year immediate pre-shock trend, shock-year log export growth relative to recent pre-shock growth, midpoint growth, and the stricter financial-crisis trend that excludes 2008. Table 6 additionally reports alternative complexity classifications, a logarithmic transformation of internet use, and fixed broadband for the pandemic.

3.3 Empirical Strategy

The baseline cross-sectional model is estimated separately for each shock

$$R_i = \alpha + \beta_1 Internet_i + \beta_2 Complexity_i + \beta_3 Internet_i \times Complexity_i + \gamma' X_i + \mu_r + \varepsilon_i \quad (3)$$

$Internet_i$ is standardized pre-shock internet use, Complexity_i is standardized pre-shock economic complexity, X_i contains standardized log income per capita, log population, and trade openness, and μ_r denotes World Bank region indicators. The interaction term tests whether internet connectivity is associated with greater export resistance in more complex economies. Heteroskedasticity-consistent HC3 standard errors are reported because the cross-section includes economies of very different sizes and because HC3 performs well in moderate samples.

The design is associational. Internet connectivity and economic complexity are measured before each crisis, which limits mechanical reverse causality from the shock-year export outcome, but the coefficients should not be interpreted as causal effects. Unobserved institutional capacity, sector composition, exposure to specific markets, commodity dependence, or crisis-specific policy responses can affect both structural indicators and export performance.

Coefficient stability is assessed by comparing the shock-specific estimates rather than by treating a pooled interaction coefficient as the main result. Table 6 reports the main measurement sensitivities. The more demanding stability tests are nonparametric and predictive. They ask whether countries keep similar positions in the export-resistance distribution across shocks and whether a compact structural model has useful predictive content within and across episodes.

3.4 Cross-Shock Persistence and Portability

Cross-shock persistence is evaluated among the 139 economies observed in both episodes. Pearson correlation measures linear persistence in the continuous resistance outcome, while Spearman correlation measures persistence in country rankings. If resilience is a stable country attribute, both correlations should be positive and economically meaningful.

A second exercise examines predictive portability. The sample is restricted to 126 economies with complete values for internet use, economic complexity, income per capita, population, trade openness, and export resistance in both shocks. Before transporting a model across crises, repeated ten-fold cross-validation with five repetitions is used to assess how much predictive content the same specification has within its own shock. A linear model is then estimated using all observations from one crisis and applied, without re-estimating the coefficients, to the other crisis. The reported statistics distinguish within-shock cross-validated R-squared from out-of-shock R-squared. A negative value indicates performance below a benchmark that predicts the relevant sample mean.

This exercise is intentionally simple and diagnostic. Its purpose is not to build an optimized forecasting system. It asks first whether a compact set of structural characteristics predicts export resistance within a crisis and, only then, whether any such predictive relationship travels to the other crisis. Weak out-of-shock performance is therefore interpreted alongside within-shock validation rather than as stand-alone evidence of coefficient instability.

4. Findings

4.1 Descriptive Evidence

Table 2 summarizes the main variables. Average internet use rose from 25.0 percent in the 2006-2008 pre-crisis window to 57.8 percent in 2017-2019. Mean economic complexity changed much less, from −0.050 before the global financial crisis to −0.017 before the pandemic. The increase in digital connectivity is therefore large enough that simple level comparisons across crises would be misleading, which is why regressors are standardized within each shock.

The average four-year-trend resistance measure is negative in both episodes. It equals −0.137 for the global financial crisis sample and −0.106 for the pandemic sample. The interpretation is that, on average, realized log export volume in the shock year fell below the level implied by the preceding country-specific trend. Among the 139 common economies, the average pandemic shortfall is about 0.032 log points smaller than the financial-crisis shortfall. The paired mean difference is not statistically precise at the conventional five-percent level, so the main evidence concerns cross-country heterogeneity rather than the average difference between crises.

Table 2. Descriptive statistics by shock

Variable	N GFC	Mean GFC	SD GFC	N pandemic	Mean pandemic	SD pandemic
Internet use (%)	142	25.030	25.663	140	57.824	27.501
Economic complexity index	142	-0.050	1.010	140	-0.017	0.998
GDP per capita, PPP	139	22,458.8	22,901.7	139	25,573.6	23,955.7
Population (millions)	142	46.2	152.2	140	53.0	169.7
Trade (% of GDP)	132	87.850	51.710	131	84.005	50.869
Export resistance	142	-0.137	0.178	140	-0.106	0.146

Note: GFC denotes the 2008-2009 global financial crisis. Export resistance is the four-year trend measure. GDP per capita is in constant 2021 international dollars.

4.2 Internet Connectivity, Complexity and Export Resistance

Table 3 reports the main cross-sectional regressions. In the global financial crisis baseline, the coefficient on standardized internet use is −0.002 with a robust standard error of 0.038. Economic complexity enters at −0.047 with a standard error of 0.033, and the interaction is −0.008 with a standard error of 0.025. None is statistically distinguishable from zero. Adding income, population, trade openness, and region indicators raises the coefficient on internet use to 0.087, with a p-value of 0.054, but the complexity coefficient and the interaction remain statistically weak. The result is therefore sensitive to specification and does not provide a clean financial-crisis connectivity premium.

The pandemic estimates are weaker still. In the baseline model, the coefficients on internet use, economic complexity, and their interaction are −0.008, 0.019, and 0.015. All are statistically insignificant. With the full controls and region indicators, the corresponding estimates are −0.010, −0.008, and 0.010. The signs of the complexity and interaction terms therefore change across specifications and shocks, and none provides stable evidence that internet connectivity and complexity jointly buffered national export volumes.

This finding differs from the generally positive firm-level evidence on digitalization. The difference is not necessarily contradictory. Firm-level studies identify whether more digitalized firms perform better than less digitalized firms within a given recession or country setting. The present outcome is aggregate merchandise export volume, which combines firms and sectors with very different exposure to the crisis. A country can contain highly resilient digitalized exporters and still experience a large aggregate export shortfall if its export basket is concentrated in sectors facing a severe global demand shock.

Alternative measurement choices reinforce the lack of a general result. Using the Standard International Trade Classification version of economic complexity makes the controlled financial-crisis internet coefficient positive and statistically significant, while the corresponding pandemic estimate remains near zero. Log-transforming internet use removes the near-threshold financial-crisis association, and fixed broadband produces no significant pandemic association. The stricter financial-crisis window that excludes 2008 also leaves the focal coefficients statistically weak. These results are reported together in Table 6. Rather than rescuing a universal connectivity-resilience claim, the sensitivity demonstrates that the apparent relationship depends on the measure and the shock.

Taken together, the main estimates do not provide robust support for H1, H2, or H3. H1 is only near the conventional significance threshold in the controlled financial-crisis specification and is not supported in the pandemic. H2 and H3 are statistically weak in both episodes under the main definitions. The hypotheses are therefore not rejected because the coefficients must be identical across shocks, but because the predicted positive associations fail to appear consistently within the two shock-specific tests.

Table 3. Internet connectivity, economic complexity and export resistance

	GFC baseline	**GFC controls**	**Pandemic baseline**	**Pandemic controls**
Internet use	−0.002 (0.038)	0.087 (0.045)	−0.008 (0.023)	−0.010 (0.038)
Economic complexity	−0.047 (0.033)	−0.027 (0.045)	0.019 (0.028)	−0.008 (0.037)
Internet × complexity	−0.008 (0.025)	−0.042 (0.029)	0.015 (0.019)	0.010 (0.025)
Controls	No	Yes	No	Yes
Region indicators	No	Yes	No	Yes
Observations	142	129	140	130
R-squared	0.081	0.217	0.014	0.088

Note: The dependent variable is four-year-trend export resistance. Continuous regressors are standardized within each shock. HC3 robust standard errors are in parentheses. Controlled models include log GDP per capita, log population, trade openness, and World Bank region indicators.

4.3 Cross-Shock Persistence

The strongest evidence against treating resilience as a fixed national attribute comes from the common-country comparison. Figure 1 plots financial-crisis resistance against pandemic resistance for 139 economies. The points are widely dispersed around the diagonal. The Pearson correlation is 0.141 with a p-value of 0.098. The Spearman rank correlation is only

0.059 with a p-value of 0.491. Countries that ranked relatively well in one shock therefore did not systematically rank well in the other.

The top of the distribution tells the same story. Thirty-five economies fall in the top quartile of resistance in each shock, but only 11 appear in the top quartile in both. The overlap is modest and is not greater than would be expected under a simple hypergeometric benchmark at conventional significance levels. The identity of the most resistant exporters is therefore not stable across the two crises.

This low persistence is not an artifact of the main four-year trend measure. Table 4 reports cross-shock correlations under alternative definitions. The Pearson correlation is 0.109 for the growth-deviation measure, 0.109 for the midpoint-growth measure, 0.134 for a three-year counterfactual trend, and 0.141 for the four-year trend. The corresponding Spearman correlations range from 0.039 to 0.061. A stricter financial-crisis counterfactual that excludes 2008 produces a Pearson correlation of 0.125 and a Spearman correlation of only 0.023. None of these correlations is statistically significant. The conclusion that country export-resistance rankings are weakly portable is therefore not driven by a single outcome definition or by including 2008 in the financial-crisis benchmark.

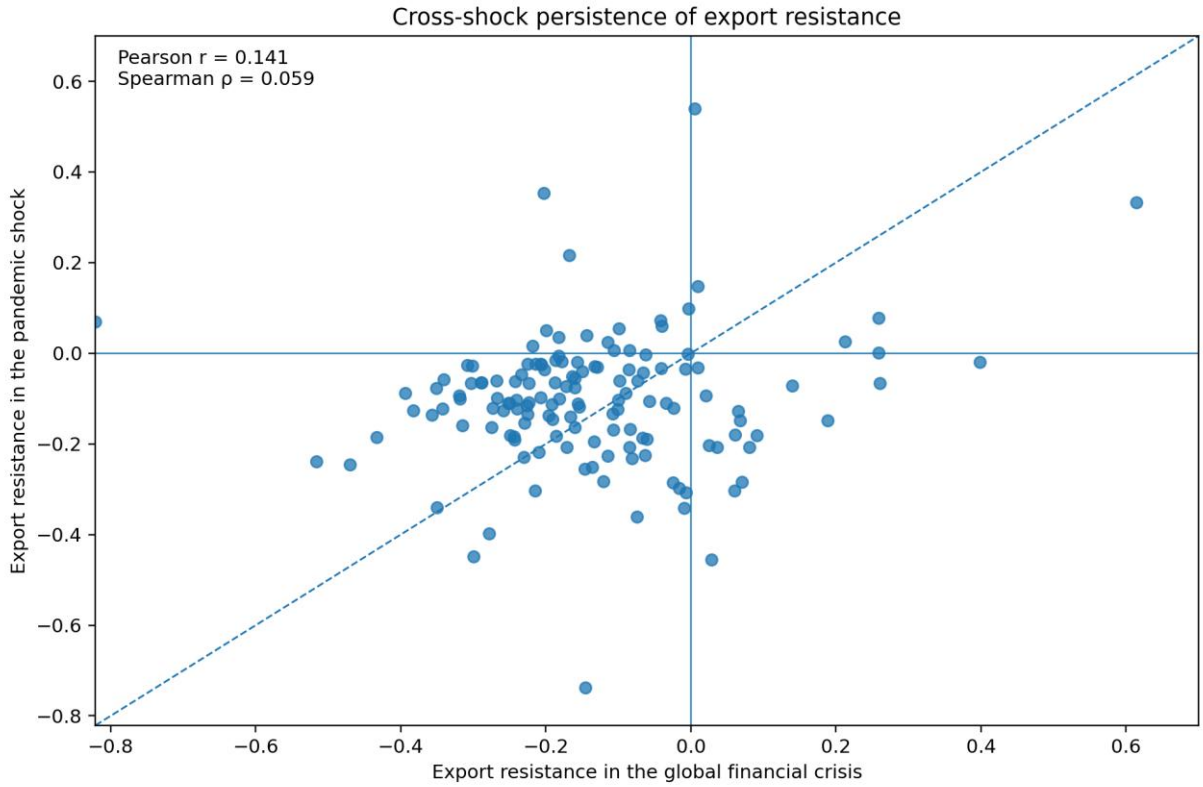


Figure 1. Export resistance across the global financial crisis and the pandemic

Table 4. Cross-shock persistence under alternative resistance measures

Resistance measure	N	Pearson r	p-value	Spearman ρ	p-value
Growth-deviation resistance	139	0.109	0.203	0.039	0.646
Midpoint-growth resistance	139	0.109	0.200	0.040	0.642
Three-year trend resistance	139	0.134	0.115	0.061	0.477

Four-year trend resistance	139	0.141	0.098	0.059	0.491
GFC trend excluding 2008	139	0.125	0.141	0.023	0.788

4.4 Predictive Portability

Table 5 evaluates predictive content within and across shocks. The results first show that the compact structural model is not a strong forecasting model even within the crisis on which it is evaluated. Repeated ten-fold cross-validation produces a mean R-squared of −0.023 for the financial-crisis specification and −0.180 for the pandemic specification. Adding the internet-by-complexity interaction does not improve validation performance. The corresponding mean cross-validated R-squared values are −0.049 and −0.229.

Cross-shock transport is also weak. A model estimated on the financial crisis and applied to the pandemic produces an out-of-shock R-squared of −0.278 without the interaction and −0.323 with it. In the reverse direction, the corresponding values are −0.084 and −0.109. These results should not be read as evidence that a strong crisis-specific forecasting relationship breaks only when moved to a new shock. The more cautious conclusion is that this small set of broad structural indicators has limited predictive content within either episode and does not become more useful when transported across episodes.

The portability exercise therefore plays a supporting role rather than carrying the main inference. The primary evidence on cross-shock stability comes from the weak Pearson and Spearman correlations in Table 4, which directly compare the same countries across crises without requiring a forecasting model. The prediction results are consistent with that evidence, but they also show that broad national indicators alone leave most of the cross-country variation in export resistance unexplained.

Table 5. Within-shock predictive content and cross-shock portability

Training shock	Test shock	Predictors	In-sample R^2	Within-shock CV R^2	Out-of-shock R^2
GFC	Pandemic	Structural indicators	0.122	−0.023	−0.278
Pandemic	GFC	Structural indicators	0.008	−0.180	−0.084
GFC	Pandemic	Indicators + interaction	0.127	−0.049	−0.323
Pandemic	GFC	Indicators + interaction	0.018	−0.229	−0.109

Note: Structural indicators are internet use, economic complexity, log GDP per capita, log population, and trade openness. The common complete sample contains 126 economies. Within-shock values are mean R-squared statistics from repeated ten-fold cross-validation with five repetitions. Out-of-shock values are obtained by fitting the model on the full training shock and applying the fitted coefficients to the other shock.

4.5 Robustness and Interpretation

The main conclusions survive several sensitivity checks. The most important concerns the timing of the global financial crisis. Because the trade collapse was already under way by late 2008, the stricter specification excludes 2008 from both the financial-crisis counterfactual trend and the covariate averages and uses 2005-2007 instead. None of the focal controlled coefficients is statistically significant in this specification. The cross-shock Pearson correlation remains only 0.125 and the Spearman correlation falls to 0.023. The main finding of weak rank persistence therefore does not depend on treating 2008 as an uncontaminated pre-crisis year.

Other checks point in the same direction while also revealing meaningful measurement sensitivity. Replacing the four-year trend with alternative growth-based resistance measures does not generate stable cross-shock persistence. Table 6 varies one measurement component at a time. HS92 is the main Harmonized System classification used to construct the Economic Complexity Index, while SITC is the alternative Standard International Trade Classification measure. The log-internet specification applies ln(1 + internet use) before standardization. Fixed broadband is measured as subscriptions per 100 people and is used only for the pandemic because comparable pre-GFC coverage is limited. The stricter GFC specification uses 2005-2007 for both the trend and the covariates. These alternatives make the robustness exercise transparent while holding the remaining controls and regional indicators constant.

Table 6. Controlled robustness estimates for export resistance

Specification	N	Connectivity	Complexity	Connectivity × complexity	R^2
GFC main HS92 and internet	129	0.087 (0.045)	−0.027 (0.045)	−0.042 (0.029)	0.217
GFC excludes 2008 from trend and covariates	129	0.108 (0.066)	−0.008 (0.070)	−0.062 (0.042)	0.211
GFC SITC complexity	129	0.107* (0.042)	−0.051 (0.033)	−0.052 (0.027)	0.226
GFC log internet use	129	0.028 (0.047)	0.001 (0.054)	−0.010 (0.023)	0.199
Pandemic main HS92 and internet	130	−0.010 (0.038)	−0.008 (0.037)	0.010 (0.025)	0.088
Pandemic SITC complexity	130	−0.004 (0.037)	−0.021 (0.031)	0.011 (0.023)	0.096
Pandemic log internet use	130	−0.031 (0.055)	−0.007 (0.040)	−0.006 (0.032)	0.089
Pandemic fixed broadband	127	−0.014 (0.038)	−0.004 (0.033)	0.005 (0.027)	0.080

*Note: The dependent variable is the four-year trend export-resistance measure except in the stricter GFC timing specification. All continuous regressors are standardized within the relevant shock sample. Each model includes log GDP per capita, log population, trade openness, and World Bank region indicators. HC3 robust standard errors are in parentheses. HS92 denotes the Harmonized System 1992 classification and SITC denotes the Standard International Trade Classification. Connectivity is internet use except in the fixed-broadband specification. The fixed-broadband model is pandemic-only because comparable pre-GFC coverage is limited. * $p < .05$. The GFC SITC internet coefficient is the only focal coefficient in the table that reaches the five-percent level, while its interaction is marginal at $p = .052$. The lack of a corresponding pandemic association and the disappearance of the GFC internet association under log transformation illustrate the measurement sensitivity discussed in the text.*

Figure 2 summarizes the preferred controlled estimates based on the main definitions. Confidence intervals for the key structural predictors overlap zero in both crises, with the financial-crisis internet coefficient providing the only near-threshold exception. Taken together with the stricter timing check, the cross-shock correlations, and the limited predictive content of the structural models, the evidence supports a cautious and shock-contingent interpretation of aggregate export resilience.

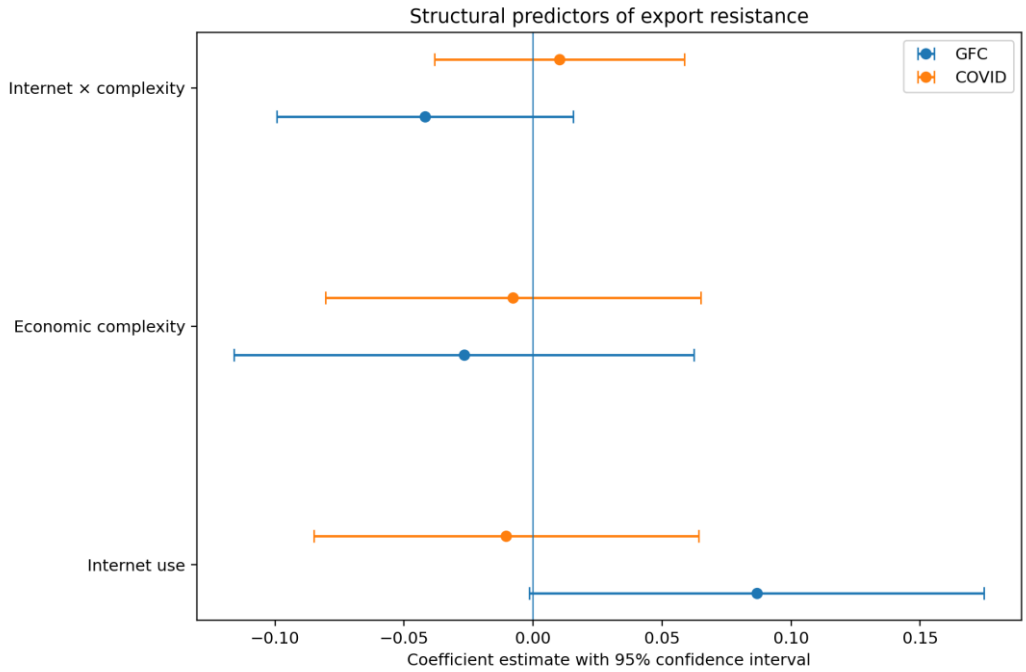


Figure 2. Controlled estimates across the two global shocks

5. Discussion

The results qualify a common intuition in the resilience literature. Digital connectivity and productive sophistication are attractive policy targets, and there are strong reasons to expect both to help firms adapt. Yet an attribute that improves adjustment within one transmission mechanism need not protect aggregate exports against another. The global financial crisis and the pandemic affected international trade through different combinations of demand, finance, mobility, production, and supply-chain channels. The weak correlation in country performance across the two episodes is therefore economically plausible rather than merely a statistical curiosity. This finding complements Hara and Yamamoto (2026), who document different gross domestic product resilience patterns across the two crises for 18 advanced OECD economies, by showing that real merchandise export resistance and its broad structural predictors are also weakly portable in a much wider international sample.

The digitalization result is especially informative. Firm-level research consistently finds benefits from digital technologies. Copestake et al. (2024) show smaller recession losses in more digitalized industries. Constantinescu et al. (2026) find that digital infrastructure amplifies the benefits of remote-work capacity during the pandemic. Li et al. (2024) document improved export resilience among digitally transforming Chinese firms after the global financial crisis. The present country-level findings do not overturn these results. They show that moving from firm or sector resilience to national export resilience is not automatic. Aggregate exports depend on the composition of the export basket, external demand, destination markets, imported inputs, commodity exposure, and the distribution of firms across sectors. Digital advantages at one margin can be dominated by losses at another.

The economic-complexity result also argues for caution. Complexity captures valuable productive knowledge and is strongly associated with long-run development outcomes

(Hidalgo & Hausmann, 2009). However, the same sophisticated production networks that provide adaptive capacity can create exposure to highly synchronized external shocks. Nguyen and Schinckus (2023) find precisely this ambiguity in a different macroeconomic setting. Bas et al. (2024) also show that the product characteristics supporting export resilience changed as the pandemic evolved. The lack of a stable positive complexity coefficient in this study is therefore consistent with a view in which capabilities matter through channels that depend on the nature of the disturbance.

One robustness result deserves explicit attention. In Table 6, replacing the main HS92 complexity measure with SITC-based complexity changes the controlled financial-crisis internet coefficient from 0.087 with a standard error of 0.045 to 0.107 with a standard error of 0.042, which reaches the five-percent significance level. This isolated result is not stable across measurement choices. The coefficient falls to 0.028 with a standard error of 0.047 when internet use is log-transformed, and no corresponding positive association appears in the pandemic specifications. The SITC result is therefore evidence of measurement sensitivity rather than evidence of a general connectivity premium. It reinforces the decision to interpret H1 cautiously and not to elevate a single specification above the broader pattern of results.

The broader implication is methodological. Evidence from one crisis should not automatically be generalized to resilience in the abstract. A country characteristic can be genuinely useful in one episode and still fail a stronger test of cross-shock portability. Researchers should distinguish at least three claims. The first is that a characteristic is associated with better outcomes in a specific shock. The second is that the relationship survives alternative measurements within that shock. The third, much stronger claim is that the characteristic predicts resilience across shocks. The evidence here is cautious even on the first two claims for the selected structural indicators and provides little support for the third across the global financial crisis and the pandemic.

This distinction also matters for policy. A generic resilience index can be useful for organizing information, but the evidence from these two crises suggests that it should not substitute for scenario-specific preparedness. The internet proxy should not be read as showing that higher population internet penetration by itself causes stronger export resilience. At most, it captures part of the enabling connectivity environment within which firms operate. When communication, mobility, or physical proximity are disrupted, policy attention should therefore extend beyond general infrastructure to exporter-level digital adoption, secure enterprise systems, e-commerce capability, remote coordination, and workforce digital skills. During credit and demand shocks, liquidity and access to trade finance may be more relevant. During supply-chain disruptions, supplier, input, and logistics diversification may matter more. The appropriate preparedness portfolio should therefore be matched to plausible transmission channels rather than inferred from a single structural indicator or a single crisis experience.

The analysis has limitations. First, annual data conceal the sequencing, depth, and speed of adjustment within a calendar year. The global financial crisis began to affect trade during 2008 and deepened into 2009, while the pandemic produced a sharp contraction and partial rebound within 2020. Annual observations therefore combine phases that may reflect different

mechanisms. A country experiencing a severe but short-lived collapse followed by rapid recovery can record a similar annual outcome to a country experiencing a smaller but more persistent decline. The resistance measure consequently captures the net annual deviation from the pre-shock path rather than the peak-to-trough loss, the timing of the trough, or the speed of recovery. This aggregation can attenuate relationships if a structural capability mainly affects recovery speed rather than the annual net shortfall. It can also mask short-lived disruptions that are large at monthly frequency but mostly reversed before year-end. The stricter 2005-2007 financial-crisis specification addresses contamination of the benchmark by late-2008 events but cannot remove the more general timing limitation. Annual frequency is nevertheless retained because it preserves a common price-adjusted export-volume concept, consistent pre-shock covariates, and broad international comparability across both crises. The estimates should therefore be interpreted as annual net resistance, not as a complete measure of dynamic resilience or recovery. Future research using monthly or quarterly product- and destination-level trade data could separate initial contraction, trough, rebound, and normalization and test whether the same structural characteristics matter at different phases of a shock.

Second, population-level internet use is a broad measure of national connectivity rather than a measure of firm digital transformation. It does not reveal whether exporting firms use cloud services, enterprise resource planning, e-commerce platforms, digital supply-chain management, cybersecurity tools, or remote-work technologies. The national indicator is appropriate for the cross-country design, but it can mask substantial sectoral and firm heterogeneity. A firm-level extension should therefore use exporter-specific digital-adoption measures and examine whether digital capabilities interact with sector exposure and firm characteristics. This limitation also narrows the policy interpretation. The results do not justify treating general internet penetration or infrastructure spending alone as an export-resilience instrument. Basic connectivity is better understood as an enabling condition. Where a shock makes digital coordination relevant, preparedness should combine reliable connectivity with sectoral and firm-level adoption support, digital skills, secure enterprise systems, and exporter-facing digital tools.

Third, the Economic Complexity Index is an aggregate capability measure and does not directly capture export diversification, destination concentration, global value-chain position, or dependence on imported intermediates. These omitted dimensions can be important for trade resilience. Fourth, the counterfactual trend is descriptive. A four-year linear extrapolation provides a transparent benchmark but cannot recover the export path that would certainly have occurred in the absence of a crisis. Finally, the cross-sectional regressions are not causal. The study intentionally prioritizes comparability and portability over causal identification.

These limitations suggest a clear research agenda. Future work could combine country-level structural indicators with product-level and destination-level exposure measures, estimate crisis-specific transmission channels, and test whether the same mechanisms recur across a larger set of shocks. A useful next step would be to distinguish resilience to demand shocks,

supply shocks, financial shocks, and mobility shocks rather than treating all major disruptions as equivalent.

6. Conclusion

This study asked whether internet connectivity and economic complexity provide a stable national export-resilience premium across two major global disruptions. Using real merchandise export volume for a broad international sample, export resistance was measured relative to a country-specific pre-shock trend. The analysis then compared the global financial crisis with the pandemic using the same empirical logic and tested whether broad structural predictors retained explanatory and predictive content across episodes.

The main result is negative but informative. Pre-shock internet use, economic complexity, and their interaction do not exhibit robust and stable associations with export resistance across both crises. More importantly, country performance itself is weakly persistent. Among 139 common economies, the Pearson correlation between financial-crisis and pandemic export resistance is 0.141 and the Spearman correlation is 0.059. Excluding 2008 from the financial-crisis benchmark leaves the same conclusion. Broad structural models also have limited predictive content within each crisis and perform poorly when transported from one to the other.

Across these two episodes, the evidence suggests that export resilience is better understood as a relationship between capabilities and a particular disturbance than as a fixed national trait. Digital connectivity and productive sophistication can remain valuable development objectives without functioning as universal insurance. Their protective value may depend on whether the capabilities they provide match the channel through which a given crisis affects production and trade.

For empirical research, the practical implication is straightforward. Evidence from one crisis should not be generalized to resilience in the abstract without validation in other settings. For policy, the implication is more limited but still useful. Broad capabilities matter for preparedness, yet the experience of the global financial crisis and the pandemic indicates that countries should combine them with contingency strategies tailored to specific transmission mechanisms. This motivates a shock-dependent preparation portfolio rather than a single generic resilience score. Table 7 translates that principle into a mechanism-based policy map. It does not rank policy instruments and it does not report estimated treatment effects. Instead, it aligns preparedness priorities with the channels highlighted by the two shocks. Demand and financial stress point toward liquidity and trade-finance resilience. Mobility and contact restrictions point toward sectoral and firm-level digital capability built on reliable connectivity. Supply-chain disruptions point toward supplier, input, and logistics diversification. The digital component deliberately emphasizes firm and sector capability rather than internet penetration alone because the national proxy used in this study does not measure firm digital transformation. The table should therefore be read as an illustrative planning framework that is consistent with the findings, not as a causal policy ranking.

Table 7. Illustrative shock-dependent preparation portfolio

Shock scenario	Main transmission	Priority preparation	Illustrative policy

	channel	capacity	instruments
Demand and financial stress	External demand contraction and tighter trade finance	Liquidity and trade-finance resilience	Export-credit guarantees, working-capital facilities, and trade-finance support for viable exporters
Mobility and contact restrictions	Limits on physical coordination, workplace access, and customer interaction	Sectoral and firm-level digital capability	Cloud and enterprise systems, e-commerce and export platforms, cybersecurity, remote coordination, and workforce digital skills
Supply-chain disruption	Imported-input shortages and logistics bottlenecks	Supplier and logistics diversification	Critical-input mapping, multi-sourcing, alternative logistics routes, and contingency inventories for essential inputs

Note: The portfolio is illustrative and organizes preparedness by transmission mechanism. The present study does not estimate causal effects of the individual policy instruments, and the table does not rank their effectiveness. The mapping translates the study's shock-contingent interpretation into practical preparedness categories.

Ethics Approval

Not required. The study uses publicly available, aggregated country-level secondary data and does not involve human participants or identifiable personal information.

Informed Consent

Not applicable.

Funding

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Conflict of Interest

The author declares no conflict of interest.

Data Availability

All source data are publicly available from the World Development Indicators and the Atlas of Economic Complexity.

Use of AI Tools

OpenAI ChatGPT was used to support language editing of the text. The scientific content, interpretations and final form of the article are the responsibility of the author.

Author Contributions

The author contributed to conceptualization, methodology, formal analysis, data curation, visualization, writing—original draft, and writing—review and editing.

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