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STRUCTURAL CORRELATES OF HIGH-TECHNOLOGY EXPORTS: EVIDENCE FROM EXPORT-ORIENTED MIDDLE-INCOME ECONOMIES

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Abstract

This study explores structural factors of high-technology export performance of export-oriented middle-income economies in 2010–2024. High-technology exports indicate value-added global value chain integration, yet the comparative influence of domestic capabilities versus external forces remains empirically contested. This ambiguity challenges mainstream assumptions regarding the universal benefits of foreign direct investment and trade openness. This study proposes a conditional structural framework to explicitly examine whether the impact of external integration varies on the depth of domestic manufacturing capacity. To address this problem, the study uses a macro-panel data framework and estimates fixed-effects models with year dummies to compensate for unobserved heterogeneity and common global shocks. Driscoll–Kraay standard errors was employed to account for heteroskedasticity, serial correlation and cross-sectional dependence. The empirical results demonstrate that trade openness and economic development (measured by GDP per capita) are the most robust and statistically significant determinants of high-technology exports. On the other hand, the impact of foreign direct investment inflows is limited and uncertain, which means that capital inflows alone are insufficient to support technical upgrading. The exchange rate is highly adversely correlated with high-technology exports, showing that currency depreciation may lead to a loss of competitiveness in technology-intensive sectors due to the reliance on imported inputs. The contribution of manufacturing value added to export performance is favorable but depends on model specification. High-technology export performance is driven by local structural capabilities and global integration rather than external capital, highlighting the need for sustained investment in domestic innovation systems, digital infrastructure, and macroeconomic stability.

Keywords: High-technology exports, Trade openness, Economic development, FDI, Exchange rate, Panel data.

INTRODUCTION

In today's global economy, exports of high technology goods are increasingly being used as a measure of structural change and international competitiveness. Countries now struggle for a competitive position not only with cost advantages but also by their ability to produce and export technologically advanced products and value chains are expanding and becoming more global. Structural factors like innovation systems, human capital, institutional quality, and digital infrastructure are key drivers of export performance in this context [1], [2], [3] .

There is a considerable amount of empirical research that has investigated the factors

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influencing high-technology exports, from various angles. The macro-level studies offer a consistent message: Structural and institutional factors are important. For example,[1] and [3] underscore the importance of human capital, governance quality, and macroeconomic stability, respectively, and [2] show the impact of the development of ICT and R&D on export sophistication on a broad sample of countries internationally. Concurrently, there is a developing body of evidence focused on the importance of digital transformation to export upgrading. Empirical findings from China and cross-country analysis indicate that digital innovation and infrastructure boost the performance of high-technology export, but this is likely due to improved export capability as well as a broader technological upgrading process [4], [5], [6]

From the micro level, the studies carried out in firms complement the above by highlighting the critical role of productivity, efficiency and firm size for export performance in technology-intensive industries [7]. Such conclusions, however, are seldom reflected in macro-level frameworks, resulting in a lack of a connection between capability-based explanations and aggregate export models. Furthermore, the literature on the link between trade openness and export performance typically assumes that openness effects are uniform and doesn't differentiate between export growth and real technological upgrading in GVCs. Likewise, while foreign direct investment (FDI) is known to be associated with technological upgrading, most macro-level studies fail to directly test the impact of FDI on upgrading in the context of the overall structural situation.

Consequently, three gaps in the literature are identified as result of this. Second, the knowledge regarding the effect of FDI on high-technology exports and absorptive capacity is still limited, as there is only weak empirical evidence in this respect, although there are strong theoretical arguments suggesting that absorptive capacity is a key determinant of the impact of FDI on high-technology exports. Second, the concept of export growth versus technological upgrading is still poorly understood, and especially when it comes to integrated production systems around the world. Thirdly, current research is often conducted in isolation, not examining the relative significance of the domestic structural factors relative to external integration pressures in an integrated empirical framework.

The gaps are especially important in countries with middle-income export orientation. Middle-income countries have an intermediate position in the global production network as compared to advanced economies with an established innovation system and low-income economies with weak industrial base. They are strongly embedded in GVCs but their ability to ongoing technological upgrading is not clear. In such cases, external integration via trade and FDI can lead to export expansion without enhancing the domestic technological capacity. This study answers three key research questions, in reply. First, is there a systematic relationship between FDI inflows and high-technology exports as to whether domestic manufacturing capacity increases or decreases? Second, does trade openness have a constant effect on within-country upgrading in the composition of exports? Third, to what extent can high-technology exports be explained by domestic structural factors, versus external forces of integration? There are three important ways in which this study is a contribution to the literature. First, it builds on an integrated analytical framework that links the domestic industrial capacity with the integration variables from abroad under a panel of middle-income export-oriented

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economies, thus overcoming the tendency to focus on OECD and single-country studies in the literature. Second, it provides a conditional perspective by explicitly testing the interaction between FDI and manufacturing capacity, as opposed to previous macro-level studies that make the assumption of homogeneous FDI effects. Thirdly, it separates export growth from technological upgrading and offers a more sophisticated understanding of high-tech exports as a measure of structural change. In this way, the study connects the micro level of evidence of capabilities with the macro level analysis of export performance.

METHOD

This study uses quantitative panel data methodology to analyse structural factors influencing high-technology exports in 10 middle-income countries that are export oriented (Indonesia, Malaysia, Vietnam, the Philippines, Thailand, Poland, Hungary, Romania, Czechia and Mexico) for the time frame 2010–2024. The panel structure is a combination of cross-sectional and time-series variation, allowing the researcher to study the dynamics within the country, in the presence of unobserved time-invariant heterogeneity. The data come from the World Development Indicators (WDI) and feature indicators of high-technology export performance, manufacturing capacity, economic development, trade openness, exchange rate, and foreign direct investment. For analytical consistency and to minimise heteroscedasticity other than due to technological upgrading, the sample is limited to structurally similar economies. A fixed-effects (FE) model with year dummies is used for the empirical analysis:

$$HighTech_{it} = \alpha + \beta_1 Manufacturing_{it} + \beta_2 lnGDP_{it} + \beta_3 Trade_{it} + \beta_4 lnEXR_{it} + \beta_5 FDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \ldots . (1)$$

To examine the conditional role of foreign direct investment, an interaction model is estimated:

$$HighTech_{it} = \alpha + \beta_1 Manufacturing_{it} + \beta_2 FDI_{it} + \beta_3 (Manufacturing_{it} \times FDI_{it}) + \beta_4 lnGDP_{it} + \beta_5 Trade_{it} + \beta_6 lnEXR_{it} + \mu_i + \lambda_t + \varepsilon_{it} \ldots (2)$$

The marginal effect of FDI is given by:

$$\frac{\partial HighTech}{\partial FDI} = \beta_2 + \beta_3 Manufacturing_{it} \ldots . (3)$$

The Hausman test is used to select the model because the reason of correlation of the regressors with the unobserved country specific factors. It is not possible to use dynamic panel estimators since the cross-sectional dimension, N = 10, is small, which can introduce weak instrument bias.

The standard errors used are Driscoll–Kraay standard errors for robustness purposes to take account of heteroskedasticity, serial correlation and cross-sectional dependence. Variance Inflation Factors (VIFs) suggest that there are no significant multicollinearity issues. Other robustness checks are conducted with alternative specifications using lagged FDI variables. While these are the strengths, there are a number of weaknesses. High-technology exports reflect export composition rather than direct outputs of innovation

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and, due to the relatively small sample size, limit external generalizability. Furthermore, the possibility of endogeneity and reverse causality, especially between the level of FDI and export performance, cannot be completely excluded. Thus, the results should be treated as 'conditional structural associations' and not as causal relationships.

RESULTS AND DISCUSSION

This section presents the empirical findings and discusses them in relation to the research questions. The analysis proceeds sequentially, beginning with descriptive statistics and correlation analysis, followed by model estimation and robustness checks. This structured approach ensures a systematic evaluation of the determinants of high-technology exports.

Table 2. Descriptive Statistics

No.	Variable	Obs	Mean	Std. Dev.	Min	Max
1.	High tech	142	24.475	16.274	6.619	67.045
2.	Manufacturing	150	20.597	3.288	13.196	30.93
3.	ln gdp	150	8.932	.664	7.615	9.934
4.	Trade	150	107.88	40.763	32.972	186.676
5.	ln exr	150	4.232	3.04	1.086	10.093
6.	FDI w	150	3.205	9.586	-33.191	59.578

Source: Author's analysis.

Table 2 reports the descriptive statistics for the variables used in the empirical analysis, revealing substantial heterogeneity across countries and over time. High-technology exports exhibit considerable dispersion, with a mean of 24.48 percent and a relatively high standard deviation (16.27). The wide range (6.62 to 67.05) reflects significant cross-country differences in technological export intensity. Manufacturing value added averages 20.60 percent of GDP, with moderate variability, indicating structural differences in industrial capacity.

Economic development, measured as the logarithm of GDP per capita, shows limited dispersion (mean = 8.93; SD = 0.66), suggesting relatively stable income differences compared to trade and export indicators. Trade openness records a high mean of 107.88 percent of GDP and substantial variability (SD = 40.76), highlighting strong but uneven external integration across the sample. The exchange rate (ln_exr) also displays significant variation, reflecting differing macroeconomic conditions.

Finally, FDI inflows, even after winsorization, remain highly volatile, with a wide range across countries and years. Overall, the statistics indicate sufficient cross-sectional and temporal variation to support panel estimation and justify the analysis of the structural determinants of high-technology export performance.

Table 3: Fixed Effects Estimation with Driscoll–Kraay Standard Errors

Variables	Baseline Model	Lagged FDI Model
Manufacturing	0.687** (0.293)	0.381* (0.184)
ln_gdp	17.591** (7.797)	11.911* (6.136)
Trade	0.054*** (0.017)	0.055*** (0.016)
ln_exr	-17.454*** (4.194)	-16.035*** (4.522)

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Variables	Baseline Model	Lagged FDI Model
FDI_w	-0.035 (0.024)	—
L1_FDI	—	-0.043* (0.024)
Constant	-81.373 (61.341)	-25.545 (47.194)
Observations	142	133
Countries	10	10
Within R^2	0.523	0.530
F-statistic	182.07	719.63
Prob > F	0.000	0.000
Year Fixed Effects	Yes	Yes
Estimation Method	Fixed Effects	Fixed Effects
Standard Errors	Driscoll–Kraay (lag=2)	Driscoll–Kraay (lag=2)

*** p<.01, ** p<.05, * p<.1
Dependent Variable: High_tech
Column (2) Standard Errors: Driscoll–Kraay (lag=2)
Year fixed effects included.

Source: Author's analysis.

Table 3 shows the fixed-effects estimates along with the standard errors computed using the Driscoll–Kraay standard errors to correct for heteroskedasticity, serial correlation and cross-sectional dependence. The results show that trade openness is positive and statistically significant for both specifications at the level of significance $p < 0.01$, indicating a stable relationship with the high-technology exports. The coefficient of the exchange rate is negative and statistically significant in both models. Similarly, manufacturing value added is positively related to high-tech exports, with the statistical significance decreasing in the lagged FDI specification. Similarly, GDP per capita is positively and statistically significant in both models with reduced significance in the presence of the lagged FDI.

In contrast, foreign direct investment (FDI) does not show a statistically significant contemporaneous effect. With the addition of lagged FDI, the coefficient is still not economically significant, though it is weakly significant ($p < 0.1$). Signs of the coefficients are consistent between the two specifications, suggesting stable within-country relationships. The positive and strong coefficient of trade openness indicates that increased trade integration leads to technological upgrading in the countries. This effect is however only a conditional one and not an automatic (see wider model results).

The negative impact of the exchange rate suggests that depreciation of the exchange rate will cause a decline in the proportion of high-tech exports. This result means that depreciation raises the costs of production in sectors which have a large dependence on imported intermediate goods, as the exchange rate is quoted in local currency units per dollar. This is in line with the architecture of middle-income economies in the global

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value chain, which rely on external capital goods and technology. Increased manufacturing value added is significantly correlated with technologically advanced exports, in support of the structural upgrading hypothesis, which suggests that improved industrial capacity contributes to generating technologically advanced exports. Likewise, the positive impact of GDP per capita is due to the accumulation of developmental processes, such as human capital, institutions, and productive capacities.

The effect of FDI is weak and unstable indicating that FDI inflows are not enough to create technological upgrading. This is even though the lagged effects are taken into account, providing a limited scale of the influence of FDI as an independent factor in high-tech export performance. In general, the results suggest that there are mainly internal structural factors behind high-tech export performance, and not so much foreign capital inflows.

Table 4. Moderation Analysis: Interaction between Manufacturing and FDI

Variables	Coefficient
Manufacturing	0.630**
ln_gdp	17.402**
Trade	0.053***
ln_exr	-17.824***
FDI_w	-0.352*
MVA_FDI	0.018*
Constant	-77.070
Observations	142
Groups	10
R^2 (within)	0.526

Dependent variable: High_tech.
Notes: *Driscoll–Kraay standard errors. Year fixed effects included.*
*** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Table 4 presents the results of the interaction model estimated using fixed effects with Driscoll–Kraay standard errors. The basic coefficients are unchanged from the baseline specification. The positive and statistically significant effect of manufacturing value added, GDP per capita, and trade openness is retained and the negative and highly significant effect of exchange rate remains. The coefficient sign of FDI becomes negative and statistically significant when the interaction term is added, and the coefficient sign of the interaction term of manufacturing and FDI is positive and slightly significant ($p < 0.10$).

The results suggest that the impact of FDI on high-tech exports is contingent on the degree of domestic manufacturing abilities. In particular, the negative coefficient of FDI indicates its impact in a situation of low level of manufacturing capacity, indicating that foreign investment does not lead to technological upgrading and that it may be related with low technological intensity where domestic production is limited.

The positive interaction term suggests that the effect of FDI is greater with higher

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level of domestic industrial capacity. This directly demonstrates that absorptive capacity determines the effectiveness of foreign investment. A key constraint on the ability of foreign companies to provide technological spillovers is the presence of domestic industries with the skills to absorb, adapt, and utilize external knowledge.

It is directly relevant to the first research question, as it shows that the relationship between FDI and high-technology exports is not a simple one, but structurally dependent. The overall results confirm a conditional development model where domestic capabilities are the main determinants of export upgrading, with foreign investment complementing and depending on domestic capabilities.

The results of this study are consistent with the finding that the performance of export high technology products is predominantly a structural phenomenon and not a short-term macroeconomic one. The positive, strong and consistent link between trade openness and high-tech exports is also found across specifications, indicating that trade openness helps to upgrade provided that the domestic environment is conducive to it, and that the nature of integration in global value chains (based on the industrial structure and the capacity for innovation) plays a role.[8].

This is supported by other evidence from ASEAN economies that indicated the significance of openness in export performance in conjunction with R&D and institutional measures [9] and ICT and innovation on export sophistication [2].

But it's not enough to be open. In the case of South Korea, this means that a sustained investment in R&D, industrial skills and digital infrastructure is required to make openness pay off in terms of technological upgrading. However, a number of middle-income commodity dependent countries with high trade-to-GDP ratios have not managed to achieve the same results because of lower quality domestic innovation systems. More support for the structural interpretation put forward by [3] comes from the positive correlation between GDP per capita and high-tech exports, which would build on the process of deeper human capital and institutional capacity accumulation. This interpretation follows a broader one that connects technological development and institutional capacity, digital infrastructure, and governance systems [10].

The exchange rate results are an important qualification to the traditional export theory. In fact, the coefficient and the t-test value are both negative and statistically significant, implying that currency depreciation will not necessarily boost the performance of high-tech exports. This result is in line with that of [11] who demonstrate that exchange rate instability has a disproportionate impact on medium- and high-technology exports.

This result is in line with the structural features of middle-income economies that are part of global value chains. Production by high technology depends heavily on imported intermediate inputs, capital goods and foreign technology. A weaker currency will therefore make production more expensive, squeeze margins and make the production less competitive. This seems to be confirmed by empirical evidence in countries like Malaysia and Thailand, where a weaker currency can boost exports of less sophisticated products, but can limit more sophisticated manufacturing. The results of this study point

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to the need for macroeconomic stability as a precondition for continuous technological upgrading.

The results related to manufacturing capacity and FDI strongly support a conditional development framework. There are positive and weak or inconsistent connections between manufacturing value added and high-tech exports, and between FDI and high-tech exports. This is in line with the overall literature that highlights the importance of domestic innovation systems and industrial structures for the impact of FDI on technological upgrading, and not as an automatic transmission channel [12]. But, once the interaction between FDI and manufacturing is added, the relation between both becomes conditionally positive, which suggests that the role of foreign investment is to improve only if there is enough domestic industrial capacity.

This result is corroborated by the results of [7] and [7] who prove that absorptive capacity is a key determinant of FDI spillovers, and by [7] who find that the ability of the firms, rather than the presence of foreign firms is key. Vietnam is a good example of this mechanism, in which FDI-induced export expansion came later when industrial areas, supply chain integration and labor skill development were established. This is aligned with the robust evidence at the firm level that innovation has a significant positive impact on firm involvement in global value chains, especially those in developing countries [7]. Otherwise, foreign investment is likely to be enclave-oriented, and have weak linkages.

This finding is also confirmed in the wider literature on digitalization [7] which indicates that technological upgrading is related to cumulative investments in innovation systems and industrial depth. The global evidence on the importance of digital innovation and new technologies for structural transformation and export competitiveness corroborates this view [7]. Overall, the results confirm a structural competitiveness view whereby the ability to upgrade exports is driven by internal forces, namely domestic capabilities, and external forces, such as FDI, have a conditional role, based on the export upgrading capability.

CONCLUSION

This study illustrates the importance of structural and macroeconomic factors in the export performance of high-tech products, above all, capital inflows. The findings reveal that trade openness is the most consistent and statistically strong indicator across all specifications and therefore plays an important role for technological upgrading through continued integration into world markets. Economic development also has a positive effect, representing the cumulative impact of human capital, institutional quality and innovation capacity. By contrast, the exchange rate exhibits a systematic negative relationship with high-tech exports, implying that "foreignization" of inputs in the global value chain within the high-tech sectors may reduce their competitiveness as the exchange rate devalues. The external capital does not have a significant independent effect, thus confirming that external capital is not enough to trigger export upgrading.

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The results support a structural competitiveness view in which high-tech exports are long term developmental accumulations, rather than short term financial and/or trade dynamics. Policy-wise, the results emphasize the importance of continuing to invest in innovation systems, high education and industrial capacity. Trade openness should be supported by policies that boost the absorptive capacity and the depth of domestic manufacturing sector, which can help economies expand their participation in higher-value parts of the global production networks without compromising macroeconomic stability. This analysis can be extended in future work by considering long-run causal mechanisms through the use of dynamic panel models and the potential endogeneity issues are also worthy of further consideration. In general, the study suggests that export performance of high technology is a result of a coordinated structural change, not of short-term capital flows or exchange rate fluctuations.

DECLARATION OF GENERATIVE AI

During the preparation of this manuscript, the author used ChatGPT (OpenAI) for language refinement, structural organization, and academic editing. Following the use of this tool, the author carefully reviewed, revised, and validated all content to ensure accuracy, originality, and academic integrity. The author assumes full responsibility for the final version of the manuscript.

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