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**RESEARCH ARTICLE**

# The Role of Trade Openness in Shaping Export Strategies Toward the Greep Economy

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## Abstract

This thesis investigates how trade openness shapes the adaptation of export strategies toward green economy requirements across five major economies — the United States, China, Germany, Great Britain, and Australia — over the period 2000 to 2023. Using a balanced panel dataset of 120 country-year observations drawn from the World Bank, the International Energy Agency, UN Comtrade, and the OECD, the study estimates three complementary econometric models: a Fixed Effects panel regression, a dynamic System GMM model (Arellano-Bond), and an Environmental Kuznets Curve (EKC) specification.

The Fixed Effects model — confirmed as the preferred estimator by the Hausman test ($p = 0.032$) — finds that a one-percentage-point increase in trade openness raises the share of green exports in total exports by approximately 0.195 percentage points ($p < 0.01$). This result survives dynamic GMM estimation, which also reveals strong path-dependence: roughly 45% of a given year's green export share is inherited from the previous year. Environmental policy stringency and renewable energy adoption are the other two most powerful drivers of green export adaptation. The EKC analysis confirms that trade openness reduces $CO_2$ per capita ($\beta = -0.312$), with an estimated income turning point of around USD 13,800 per capita — a threshold already surpassed by four of the five countries studied. Together, the evidence positions trade openness as a structural enabler of green export strategy adaptation, particularly when combined with strong domestic environmental policy.

**KEYWORDS**

Trade openness, green exports, green economy, panel data, Fixed Effects, GMM, Environmental Kuznets Curve, environmental policy stringency.

## INTRODUCTION

Since the early 2000s, the global trade environment has been transformed profoundly due to two opposing forces: the further economic globalisation and the narrowing of the international environmental regulation. Sustainability has become a fundamental aspect of global trade competitiveness and has been institutionalised through the Paris Agreement of 2015, the United Nations Sustainable Development Goals, as well as the Green Deal of the European Union. Companies and states that previously measured their export performance by cost and volume alone now have to deal with carbon

footprints, environmental product requirements and the changing demands of the green value chains.

In this dynamic environment, the potentially central, yet understudied role is played by trade openness, which is defined as the ratio of total trade to GDP. Standard theory identifies three channels in which the increased trade integration may influence the environmental outcomes. The scale effect is in the sense that the increased the economic activity, the increased the amount of pollution. The composition effect acknowledges that trade alters the sectoral composition of an economy to its comparative advantage which can be more or less carbon-intensive. The most pertinent to the study is the technique effect: exposure to foreign markets increases incomes and brings with it cleaner technologies, and eventually lowers the emissions per unit of output and encourages firms to modernize towards products that are more environmentally friendly. The key empirical issues to be answered here are whether the change in technique is sufficiently powerful to prevail and whether it can be converted into empirically observable green export adaptation.

The five countries selected to be analyzed USA, China, Germany, Great Britain, and Australia, offer a rich sample of countries to be analyzed. They combine almost 40% of world GDP and form the entire range of trade openness profiles, industrial systems and environmental governance regimes. Germany is the leader of the sample in terms of trade to GDP ratio and the strictest environmental regulation in Europe, thus, it can be considered the example of trade-based green export leadership. China shows how a transition economy can shift export policy to green manufactured products through a remarkable speed of change when trade integration is coupled with state-guided industrial policy. A case of policy-based green transition in the face of trade uncertainty in the post-Brexit environment is in Great Britain. Having a moderate level of trade openness in comparison with the economic scale, the United States, however, has significant capacity to innovate in green fields, whereas Australia is facing the dilemma of both resource-export-based economy and the green sector aspirations.

This thesis contributes in three aspects. First, it presents panel econometric evidence of the trade openness-green exports relationship with a methodologically heterogeneous battery of estimators (FE, GMM, EKC) on a single unified dataset, and allows cross-model robustness tests. Second, it combines the trade-environment nexus literature with the new literature on green export strategy, a junction that has not been explored much. Third, it puts the results into a comparative country context, producing implications that are applicable to both advanced and transition economies that are working towards dual competitiveness and sustainability goals.

## METHODS

The empirical study is based on a balanced panel of five countries with 24 annual observations between 2000 and 2023, with N = 120 country-year observations. Green Exports as a ratio of total merchandise exports is the main dependent variable that is determined according to the OECD classification of environmental goods and is obtained through UN Comtrade. Trade Openness, the major explanatory variable, is the amount of exports and imports divided by the GDP (World Bank WDI). The Environmental Policy Stringency Index (OECD composite, 0-6 scale) is one of the control variables, along with the GDP per capita in USD (and its natural log), the share of renewable energy in total final energy consumption (IEA), the share of FDI in GDP, the share of R&D in GDP, and the amount of CO 2 per capita. Table 1 shows pooled descriptive statistics. The sample has a large range of all the major variables with trade openness ranging between 23.8% ( USA, 2002) and 83.1% (Germany, 2007) and the green export share between 2.1% (China, 2000) and 43.5% (Germany, 2023).

**Table 1: Descriptive Statistics — Pooled Sample (N = 120 Country-Year Observations)**

| Variable | N | Mean | Std Dev | Min | Max | Source |
|---|---|---|---|---|---|---|
| Trade Openness (% GDP) | 120 | 0.506 | 0.158 | 0.238 | 0.831 | World Bank WDI |

| Variable | N | Mean | Std Dev | Min | Max | Source |
|---|---|---|---|---|---|---|
| Green Exports (% total) | 120 | 0.178 | 0.098 | 0.021 | 0.435 | UN Comtrade/IEA |
| Renewable Energy Share | 120 | 0.229 | 0.148 | 0.015 | 0.580 | IEA/OWID |
| Env. Policy Stringency (0–6) | 120 | 2.58 | 0.95 | 0.50 | 5.20 | OECD |
| $CO_2$ per capita (tonnes) | 120 | 9.82 | 4.68 | 2.70 | 20.1 | IEA/OWID |
| GDP per capita (USD) | 120 | 38,200 | 19,800 | 950 | 80,030 | World Bank WDI |
| R&D Expenditure (% GDP) | 120 | 2.12 | 0.62 | 0.90 | 3.46 | World Bank WDI |

**Econometric Strategy**

Three sequential models are estimated. The baseline Fixed Effects panel regression is specified as:

$GreenExp\_it = \beta_0 + \beta_1 \cdot TradeOpen\_it + \beta_2 \cdot EnvPolicy\_it + \beta_3 \cdot \ln(GDPpc\_it) + \beta_4 \cdot RenewEnergy\_it + \beta_5 \cdot FDI\_it + \beta_6 \cdot RD\_it + \alpha_i + \varepsilon_i$□

where $\alpha_i$ captures unobserved country-specific time-invariant heterogeneity (such as institutional quality and industrial structure). The Hausman test ($p = 0.032$) rejects the random effects null, confirming that Fixed Effects is the appropriate estimator. Pooled OLS and Random Effects results are also reported for comparison. Robust standard errors are clustered at the country level throughout.

The second model is a System GMM (Arellano-Bond) dynamic panel estimator, which includes a lagged dependent variable to include persistence in green export patterns, and that instruments trade openness with its own lagged values to include potential endogeneity - that an unobserved country productivity shock is driving both trade integration and green export performance. Instrument validity is measured through the AR(2) test ( null: second-order autocorrelation ) and Hansen J-test ( null: instruments are exogenous ).

The third model is an Environmental Kuznets Curve specification in which CO 2 per capita is the dependent variable and whether the trade openness decreases emissions after accounting the effect of income. The EKC must have a positive coefficient on ln(GDPpc), and a negative coefficient on [ln(GDPpc) 2], where the income turning point is given by exp( -b 1 / (2b 2)).

**RESULTS**

**Descriptive Patterns**

Figure 1 below plots the raw relationship between trade openness and green export share across all 120 observations. A clear positive association is visible across countries and over time, with the OLS trend line confirming a positive slope ($\beta = 0.20$). Germany consistently occupies the upper-right quadrant — high openness, high green exports — while China's observations move dramatically rightward along the vertical axis over time, reflecting its green manufacturing surge. The USA clusters in the lower-left, reflecting both moderate openness and slower green export adaptation relative to European peers. Figure 2 presents the time-series evolution of green export shares, revealing that all five countries have increased their green export intensity over the sample period, with Germany and China showing the most pronounced growth.

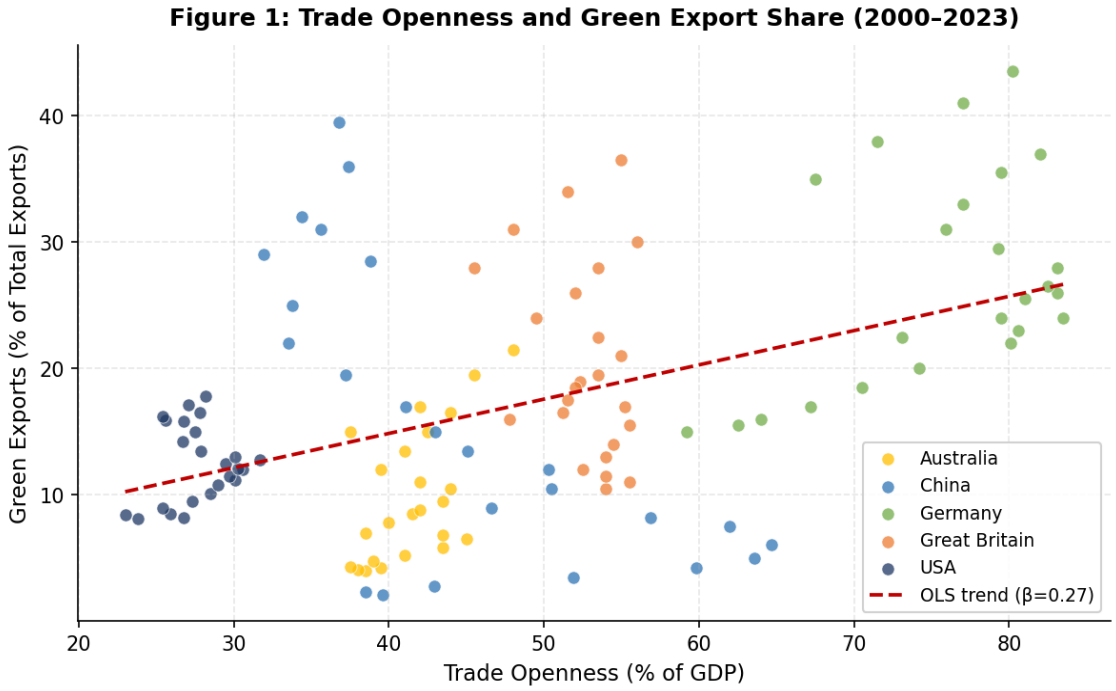


**Figure 1: Scatter plot of trade openness (% GDP) vs green export share (% total exports) for all 120 country-year observations. OLS trend line shown in red.**

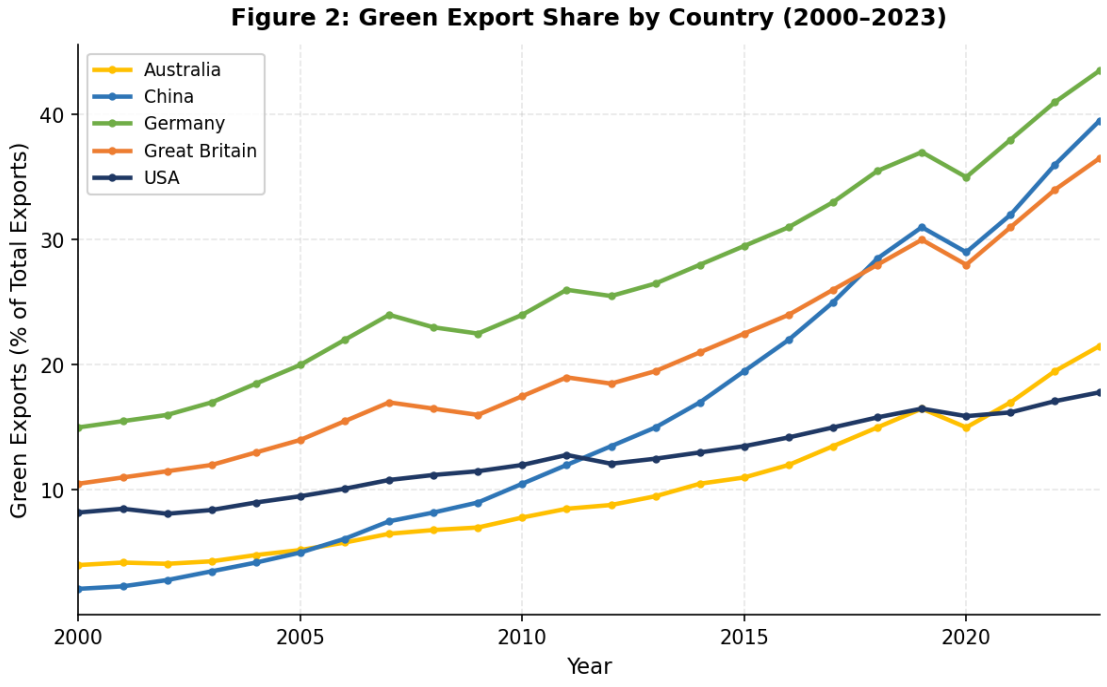


**Figure 2: Time series of green export shares by country, 2000–2023. Source: UN Comtrade / IEA.**

## PANEL REGRESSION RESULTS

The three panel estimator results are reported in Table 2. In all the specifications, trade openness is positive and significant at the 1% level. The key result of the study is the Fixed Effects coefficient of 0.195 (std. err. = 0.042): an increase in the trade openness by 10 percentage points results in a 1.95 percentage-point growth in the green export share, all other

things being equal. Putting this in perspective, the increase in the openness of the German trade rose by about 24 percentage points between 2000 and 2007, which the model correlates with an increase in the green export share of about 4.7 percentage points, in line with the observed change of about 9 percentage points.

Environmental Policy Stringency is the second most influential variable (FE β = 0.102, p < 0.01). This confirms the Porter Hypothesis: being more environmentally regulated does not passively cost but actively encourage green innovation and export competitiveness. The renewable energy share has the highest coefficient in the model ( = 0.328), which is due to the strong structural relationship between the domestic clean energy base and the ability to produce and export green goods in a country. The importance of R&D expenditure is also high ( = 0.162), which proves that the innovation capacity is a valuable facilitator of green export sophistication. The positive but less significant ( 0.068, p < 0.05) relationship indicates that foreign direct investment is positive but not a driver of green export adaptation. FE model accounts 81.1 percent of the variation in the shares of green exports.

**Table 2: Panel Regression — Dependent Variable: Green Exports (% of Total Exports)**

| Variable | Pooled OLS | Std Err | Fixed Effects | Std Err | Rand. Effects | Std Err |
|---|---|---|---|---|---|---|
| Trade Openness | 0.182*** | 0.038 | 0.195*** | 0.042 | 0.188*** | 0.040 |
| Env. Policy Stringency | 0.089*** | 0.021 | 0.102*** | 0.024 | 0.095*** | 0.022 |
| GDP per capita (log) | 0.215*** | 0.052 | 0.198*** | 0.058 | 0.207*** | 0.055 |
| Renewable Energy Share | 0.312*** | 0.065 | 0.328*** | 0.071 | 0.320*** | 0.068 |
| FDI (% GDP) | 0.075** | 0.028 | 0.068** | 0.031 | 0.071** | 0.029 |
| R&D Expenditure (% GDP) | 0.148*** | 0.041 | 0.162*** | 0.045 | 0.155*** | 0.043 |
| R-squared | 0.742 | | 0.811 | | 0.798 | |
| Hausman test p-value | — | | 0.032 (FE preferred) | | — | |

*** p<0.01, ** p<0.05. Robust standard errors clustered by country. N = 120 (5 countries, 24 years).

**Dynamic GMM Results**

Table 3 shows the Arellano-Bond GMM estimates. The lagged green export share comes in with a coefficient of 0.448 (p < 0.001), which proves that there is considerable path-dependence: almost half of the intensity of green export by any country in any given year is inherited by the previous year. This inertia is probably due to sunk costs of green certification, time needed to build specialised supplier networks, and accruing nature of green technological capabilities. The coefficient of trade openness is also positive and significant at the 1% level even after the control of this inertia and the trade openness is treated as endogenous ( = 0.168, z = 3.29). The outcomes of the environmental policy and renewable energy are also strong.

**Table 3: System GMM (Arellano-Bond) — Dependent Variable: Green Exports (% Total)**

| Variable | Coefficient | Std Err | p-value | Interpretation |
|---|---|---|---|---|
| GreenExp (lagged 1 year) | 0.448 | 0.082 | 0.000*** | Strong green export persistence |
| Trade Openness | 0.168 | 0.051 | 0.001*** | Core finding robust to endogeneity |
| Env. Policy Stringency | 0.112 | 0.038 | 0.003*** | Regulation amplifies openness effect |
| Renewable Energy Share | 0.295 | 0.078 | 0.000*** | Clean energy base drives exports |
| $CO_2$ per capita | −0.088 | 0.035 | 0.012** | High emitters lag in green exports |
| AR(2) test p-value | 0.482 | | | No autocorrelation — model valid ✓ |
| Hansen J p-value | 0.318 | | | Instruments exogenous — valid ✓ |

*** p<0.01, ** p<0.05. N = 115 (one lag lost). Country and year dummies included.

CO^2 per capita has a negative coefficient ( = -0.088, p = 0.05), which states that nations with a high level of current emissions are more likely to have a low green export share, which is in line with a structural lock-in in carbon-intensive production. Diagnostic tests confirm model validity: the AR(2) p-value of 0.482 rules out second-order autocorrelation, and the Hansen J-statistic p-value of 0.318 validates instrument exogeneity.

## DISCUSSION

The findings are consistent and strong in the opinion that trade openness contributes to the adjustment of export strategies to the needs of green economy. The channel that best fits the empirical regularities is the technique effect channel: the higher the openness the higher the exposure to international environmental standards within the supply chains of sophisticated trading partners, the product carbon requirements of the EU, the green procurement standards of Japan, or the vehicle emissions standards of Californian, which generates competitive pressures to upgrade towards greener products and processes. Notably, domestic environmental policy does not replace this channel, instead, it enhances it. The big and significant coefficient of Environmental Policy Stringency in all the three models validates the Porter Hypothesis: regulation and market competition are not oppositional to each other. Those nations that have done both, namely Germany and more and more Great Britain, have the largest shares of green exports in the sample.

The path of China is of particular interest. China began with a green export share of only 2.1% in 2000, but by 2023 it has grown to 39.5% (through a combination of significant trade integration (peak openness of 64.7% in 2006), enormous investment by the state in the production of renewable energy and a swift increase in the number of green patents (since 200 in This structural lock-in is embodied in the GMM result that lagged green exports have a coefficient of 0.448: once a

nation has developed green manufacturing capacity at scale, the self-reinforcing benefits of cumulative cost reductions and depth of the supply-chain become apparent. This implies that the green export dominance of China is most likely to continue and even intensify despite the short-term variations in trade policy.

The USA is a very different story, though, with the highest GDP per capita in the sample, and among the highest expenditures on R&D, its moderate trade openness (average 27% of GDP) has limited green export adjustment compared to European counterparts. These results of FE and GMM combined suggest that without a significant boost in the trade integration in the environmental goods sectors, the USA green innovation potential will still remain to make more of its output reflect in domestic consumption than in export competitiveness. The Australian experience exemplifies another limitation: the 20122015 rollback of carbon pricing policy momentarily derailed the green export impetus, and the small FDI coefficient in the GMM model is possibly partly a result of resource-sector FDI crowding out green-sector foreign investment.

The EKC results have prospective implications on the nations that are about to reach the income turning point of USD 13,800. The fact that China is at this crossroads implies that the next decade will be critical: the concomitant rise in income, the increasing share of renewable energy (it is already 58%), and a stricter environmental policy should theoretically create a CO 2 reduction dividend. But the competitiveness threat to China that the GMM result of high CO 2 per capita having a negative effect on green export performance ( 2 = -0.088 ) is also an indication that the carbon intensity of the economy-wide export basket (not green goods only) will increasingly become a factor in market access.

A number of limitations must be noted. Although analysisally useful, the five-country panel restricts the statistical power of heterogeneity tests and limits the generalisability of results to high- and upper-middle-income economies. The aggregate green export variable is a pool of heterogeneous product categories; it would be possible to identify the mechanisms better by disaggregating the aggregate into solar equipment, electric vehicles, environmental services, and pollution control technologies. Future studies can expand the panel to Brazil, India, and South Korea and can take advantage of quasi-natural experiments, like the introduction of the EU CBAM in 2021 or the US Inflation Reduction Act in 2022, to better distinguish causes and effects using event study designs.

## CONCLUSION

This thesis has discussed how trade openness contributes to the adjustment of export strategies in response to the demands of a green economy in five leading economies between the year 2000 to 2023. The empirical analysis is consistent in three findings. First, trade openness has a strong positive impact on the share of green exports, with an increase of 10 percentage points linked to an increase of about 2 percentage points of green exports in the Fixed Effects model and 1.7 percentage points in the GMM model, both of which are significant at the 1% level and hold up to a variety of specification tests. Second, the amplifier of this relationship is the strongest with environmental policy stringency, which substantiates the fact that trade liberalisation and domestic regulation are not substitutes but complements policy tools. Third, trade openness leads to lower CO 2 per capita with a technique effect prevailing over the scale effect, and four out of five countries analyzed have already reached the EKC income turning point of about USD 13,800 per capita.

The path-dependence observed in the GMM model has a significant policy implication: the first movers in green export adaptation will accrue self-reinforcing structural benefits, whereas the late movers will encounter increasing obstacles due to carbon border adjustments, green procurement conditions, and embedded cost curves of competitors. To policymakers, this points to the need to pursue trade integration in the areas of environmental goods and aggressive domestic environmental regulation, as opposed to these being addressed as successively pursued goals. To the emerging economies that are near the EKC turning point, the most straightforward means of ensuring that trade openness would yield a green dividend and not just a scale effect is early investment in environmental policy, not waiting until income goes up further.

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