HIGHER SCHOOL OF ECONOMICS
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Trade in Low Carbon Goods and Reduction of Fuel Combustion Emissions in Russian Regions

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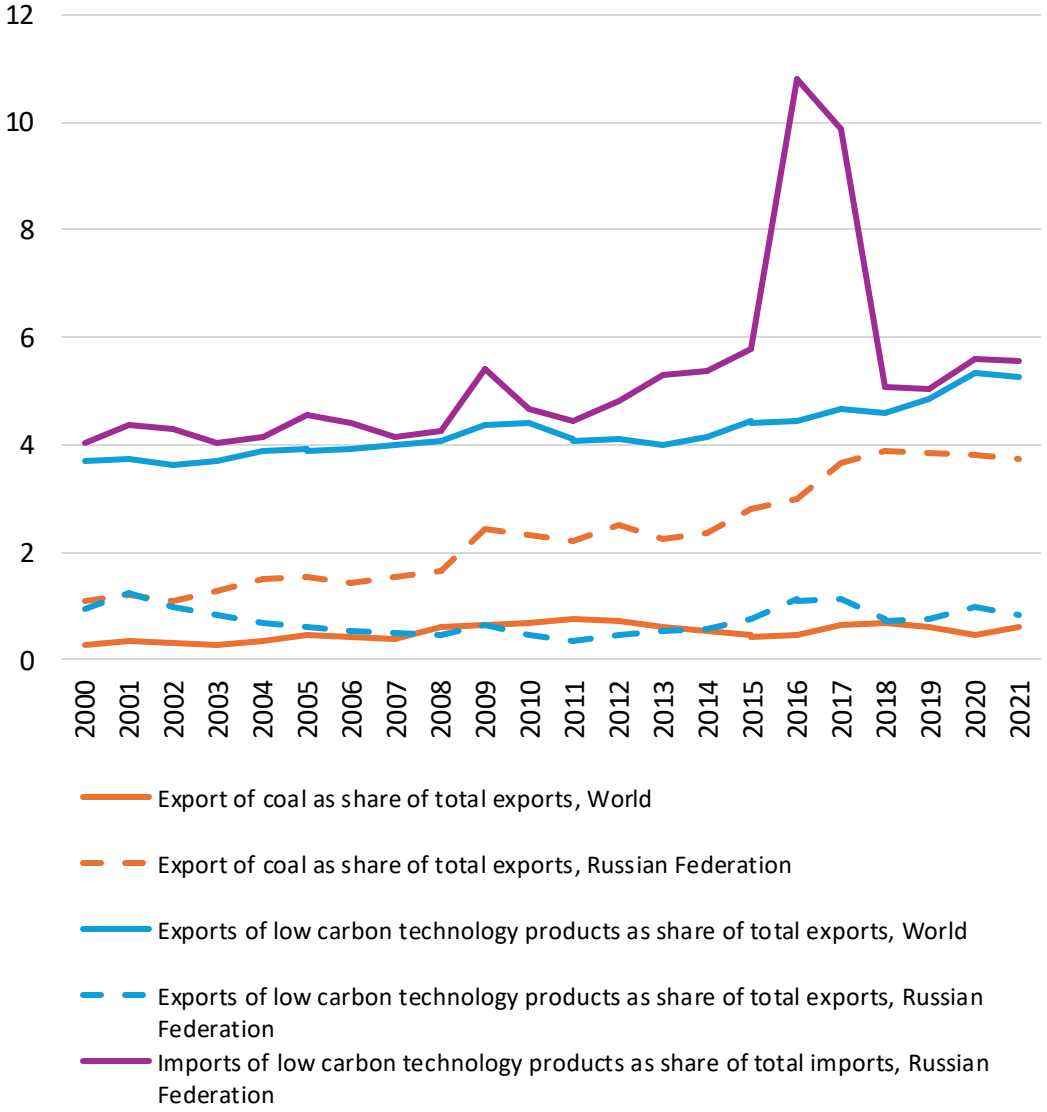
Introduction

- **Context and Growing Interest:**
  Over the past decade, there has been a surge in interest around the production and use of low-carbon goods (LCGs), driven by the increasing frequency of environmental disasters and the urgency to meet the **United Nations Sustainable Development Goals** (Haas et al., 2023; Knutti et al., 2010).
- **Advantages of Low-Carbon Goods:**
  LCGs, such as **solar panels, wind turbines**, and **electric vehicles**, are more environmentally friendly, offering lower emissions compared to carbon-intensive alternatives. They provide benefits across various sectors and regions, but face challenges like high initial costs and the need for **efficient infrastructure** (Mealy, Teytelboym, 2022).
- **Barriers to Green Technology Adoption:**
  Despite growing interest, **green technologies** face significant barriers due to uncertainties around **climate change, technological advancements**, and **environmental policies**. These challenges have slowed the growth of **green and renewable products** in global trade, with their share of trade volume remaining relatively low over the last 20 years (Mealy, Teytelboym, 2022).
- **Trade in LCGs:**
  The **share of LCGs** in global exports grew only marginally from 3.7% in 2000 to 5.3% in 2021, with **global coal trade** also expanding during this time, reflecting the **complex dynamics** in the transition to a low-carbon economy.

Russia's Low Carbon Goods (LCG) Trade: Complex Trends and Regional Variability



Source: Compiled by the authors based on the International Monetary Fund. 2022.Climate Change Indicators Dashboard.Retrieved from https://climatedata.imf.org/pages/access-data (05.05.2024).

Russia's Low Carbon Goods (LCG) Trade: Complex Trends and Regional Variability

•Slow Growth in LCG Exports

- From 2000 to 2021, **Russia's LCG exports** have remained below 1% of total exports.
- Despite efforts, **no significant increase** in LCG export share over this period.

•Increase in LCG Imports

- **LCG imports** have risen from 4% of total imports in 2000 to **5.6% in 2021**.
- Notably, **LCG imports surpassed 10%** in 2016-2017.

•Recent Developments in Low-Carbon Economy

- **Low-carbon economy agenda** in Russia has only gained momentum in recent years.
- While **global integration in low-carbon technologies** shows promise, **local implementation remains modest** (Bashmakov, 2019; Popova, Kolmar, 2023).

•Regional Differences in Energy Systems

- Russian regions exhibit **significant variation** in the structure and efficiency of their energy systems.
- Varied approaches to **pollution reduction** and environmental impact mitigation (Khrustalev, Ratner, 2015).

•Challenges in Data and Methodology

- **Data uncertainty** in assessing **LCG production and use** at the regional level.
- Development of economic projects requires consideration of **diverse social, environmental, and economic factors** (Ratner, 2016).

Our approach

- **Focus on Regional Heterogeneity**
  - Continue research into the **heterogeneity of sustainable development** across Russian regions.
- **Goal:** Expand understanding of **sustainable development indicators** and their link to **fuel combustion emission reductions**.

Our approach (2)

Main Hypothesis: The relationship **between trade in LCGs** and **emission reduction** is **nonlinear** in Russia due to:

- Significant **differences in regional competencies**.
- **High regional disparities** in development and infrastructure.

Definition of LCGs

- **Complexity in Defining LCGs**
  - Identifying LCGs is a **complex task** (Pigato et al., 2020).
  - **WTO Environmental Goods Agreement (2016)** failed due to disagreements on LCG lists (De Melo & Solleder, 2019).
- **Proposed Framework for LCG Identification**
  - **Pigato et al. (2020)** suggest using three widely recognized lists:
    - **World Bank**
    - **APEC (Asia-Pacific Economic Cooperation)**
    - **Academic researchers** (Glachant et al., 2013).

Commodity Structure of Russian LCGs Exports and Imports (2016-2021)

Top 3 LCGs Exports (Russia's Share in Gross Exports)

- **Heat Exchange Units (2.1%)**
  - Essential for **energy-efficient heating/cooling systems** (e.g., heat pumps, waste heat recovery).
  - Contributes to **global sustainable energy** efforts by reducing emissions.
- **Measuring/Checking Instruments (1.6%)**
  - Critical for **monitoring low-carbon technologies** (renewable energy, smart grids).
  - Helps optimize **energy efficiency** and minimize environmental impact.
- **Electrical Control Distribution Bases (1.5%)**
  - Vital for managing electricity in **renewable energy systems** (solar, wind).
  - Supports **smart grids** and **energy storage** to improve energy system reliability.

Top 3 LCGs Imports (Russia's Share in Total Imports)

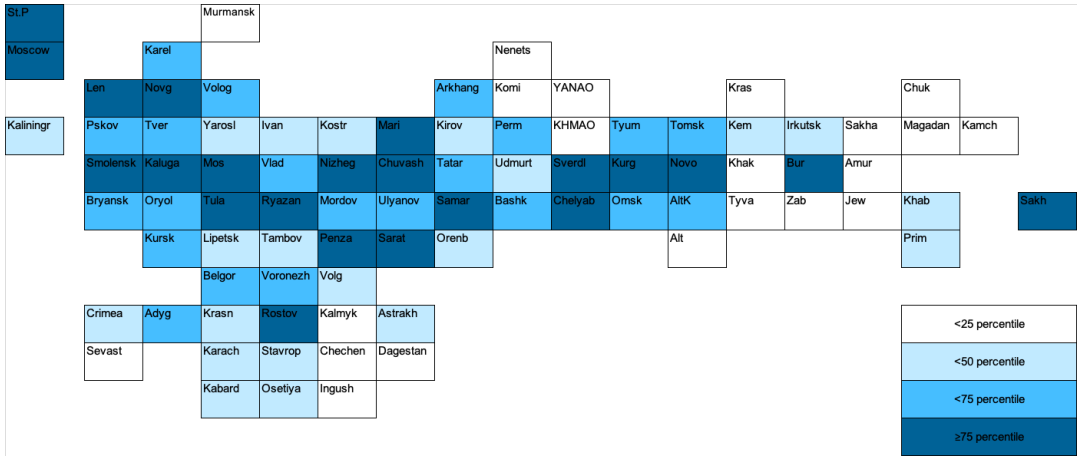
- **Machinery for Liquefying Air or Gases (15.3%)**
  - Supports **renewable energy production** and **carbon capture technologies**.
  - Highlights **dependency on advanced equipment** for sustainable energy.
- **Electrical Control & Distribution Apparatus (9.0%)**
  - Key for managing **electricity in renewable systems** (solar, wind).
  - Improves **efficiency** and **reliability** of low-carbon infrastructure.
- **Machines & Mechanical Appliances (7.9%)**
  - Used for manufacturing **components** (electric motors for wind turbines, EV batteries).
  - Crucial for **Russia's renewable energy development**.

Distribution of LCGs across Russian regions

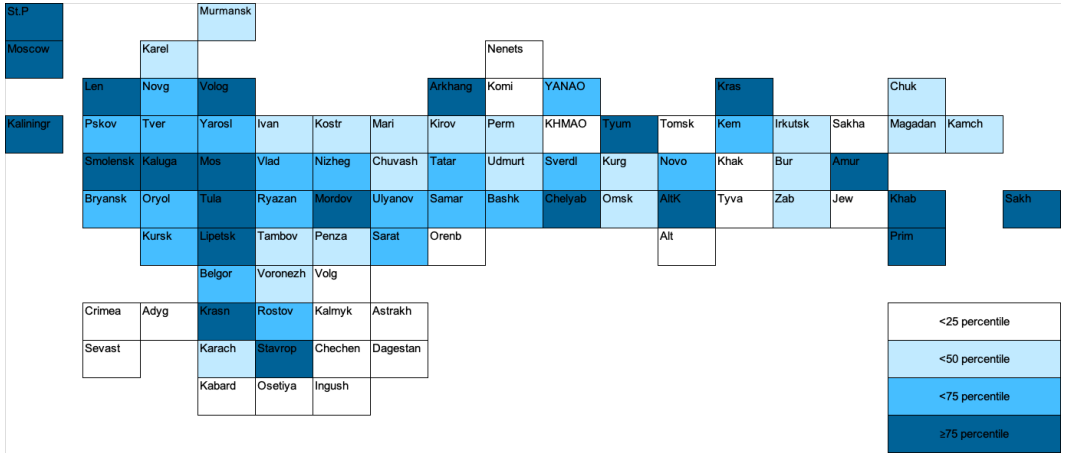
Contribution of LCGs as a Percentage of Gross Exports, Imports, and GRP in Russian regions, Average for 2016-2021

Federal District	LCG Exports (% of Gross Exports)	LCG Exports (% of GRP)	LCG Imports (% of Gross Imports)	LCG Imports (% of GRP)
Ural Federal District	3.238	0.194	0.137	0.023
Southern Federal District	2.162	0.059	0.379	0.041
Siberian Federal District	2.103	0.254	0.050	0.007
Northwestern Federal District	2.074	0.314	0.095	0.005
Volga Federal District	0.914	0.094	0.586	0.030
Central Federal District	0.615	0.013	1.105	0.054
North Caucasian Federal District	0.510	0.126	0.552	0.022
Far Eastern Federal District	0.153	0.046	1.555	0.147
Russian regions (average)	1.467	0.153	0.511	0.039
Russian regions (minimum)	0.000	0.000	0.000	0.000
Russian regions (maximum)	20.204	3.385	13.357	1.912
Russian regions (median)	0.553	0.063	0.052	0.004

Share of LCG exports in GRP across Russian regions (%), average for 2016-2021



Share of LCG imports in GRP across Russian regions (%), average for 2016-2021



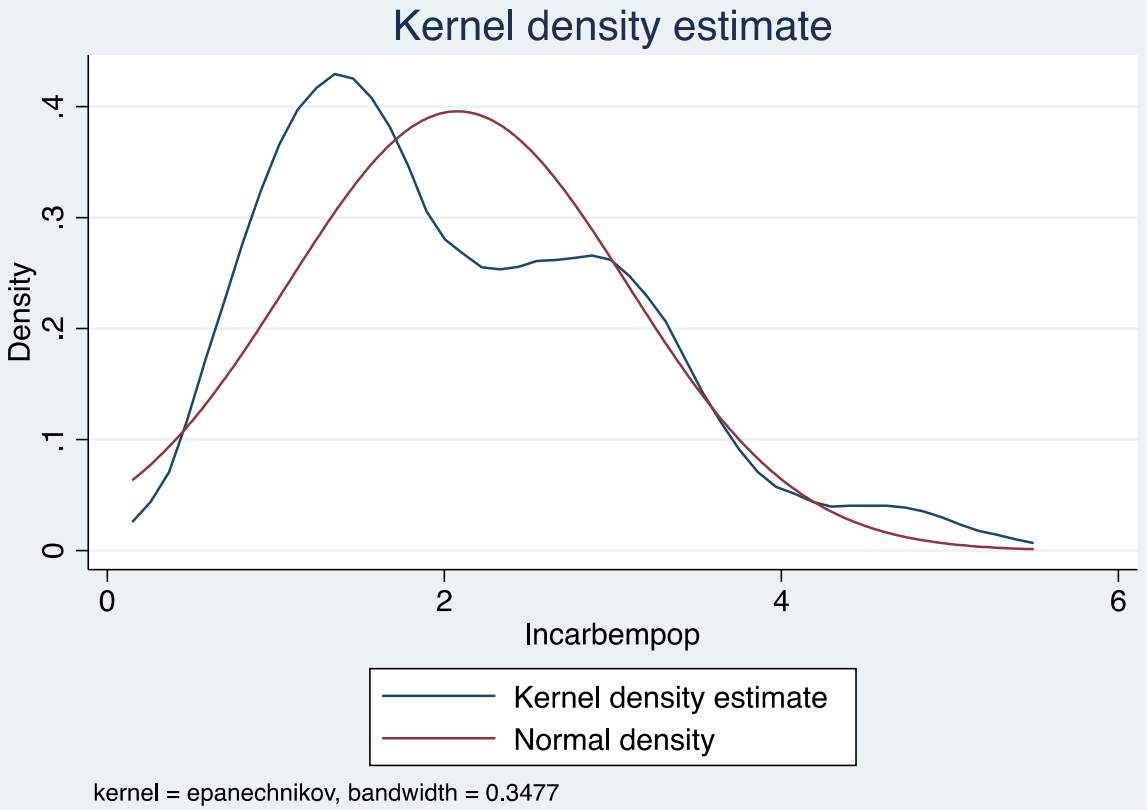
Theoretical Frameworks in Environmental Economics & Regional Development

- **Environmental Kuznets Curve (EKC) Hypothesis**
  - **Inverted U-shaped relationship** between economic growth and environmental degradation.
  - **Initial deterioration** in environmental conditions during economic growth, followed by **improvement** as economies mature and adopt cleaner technologies.
  - Validated in studies of the Russian economy (Mariev et al., 2020; Shkiperova, 2013).
- **Foreign Direct Investment (FDI)**
  - **Pollution Haven Hypothesis**: FDI can increase emissions in regions with **lax environmental regulations**.
  - **Pollution Halo Hypothesis**: FDI can reduce emissions via **technology transfer** and **innovation** (Cole, 2004; Zarsky, 1999).
- **Porter Hypothesis**
  - **Environmental regulations** can drive **innovation** and **resource efficiency** in manufacturing (Porter, van der Linde, 1995).
- **Urbanization & Emissions**
  - Densely populated regions tend to have **higher energy consumption and emissions**, but may benefit from **cleaner infrastructure** and governance (York, Rosa, & Dietz, 2003).
- **Trade & Environment Nexus**
  - **Low-carbon goods trade (LCGs)** influences emissions through **scale** and **technique effects** (Copeland, Taylor, 2004).
- **Comprehensive Framework**
  - These theories form the foundation for understanding the **environmental impacts** of LCG trade across Russian regions.

Variables for the empirical model

Variable name	Definition	Data source	References
Dependent variable			
lncarbempop	Emissions of pollutants into the atmosphere from fuel combustion (for electricity and heat generation) (carbon oxide) thousand tons per thousand population, logarithm	EMISS	Mariev et al., 2020;
Explanatory and control variables			
lnlctimpop	Import of LCGs per capita, USD, logarithm	Authors' calculations	
lnlctexppop	Export of LCGs per capita, USD, logarithm	Authors' calculations	
lngrppc	GRP per capita, RUB, logarithm	Rosstat	Ali et al., 2019; Muhammad et al., 2020; Xu, Lin, 2016; Mariev et al., 2020;
lngrppc2	Square of GRP per capita, RUB, logarithm	Authors' calculations	Grossman, Krueger, 1991; Xie, Liu, 2019; Mariev et al., 2020; Schkiperova et al., 2013;
ifdipop	Inflow of foreign direct investment per thousand population, million USD, logarithm	Central Bank of Russia	Muhammad et al., 2020; Mariev et al., 2020;
lnamtpop	Number of advanced manufacturing technologies used per thousand population, logarithm	Rosstat	Xie, Liu, 2019; Mariev et al., 2020;
lnenergyconspop	Electricity consumption per thousand population, million kWh	Rosstat	Ali et al., 2019; Muhammad et al., 2020; Mariev et al., 2020;
cityshare	Urban population share, %	Rosstat	Ali et al., 2019; Muhammad et al., 2020; Xie, Liu, 2019; Xu, Lin, 2016; Mariev et al., 2020;

Analytical Methods: Tobit and Quantile Regression



Tobit Method

•**Purpose:** Used for data with a **non-uniform distribution** and a **bounded dependent variable** (ranging from -3 to 6).
•**Suitability:** Ideal for **censored data** (bounded above and/or below), commonly seen in socio-economic and psychological phenomena.

Quantile Regression

•**Purpose:** Alternative estimation method for analyzing relationships across different **quantiles** of the dependent variable.
•**Advantages:**

- Captures **non-uniform data distributions** and **variation across quantiles**.

Trade in LCGs as a Determinant of Pollutant Emissions from Fuel Combustion: Quantile Regression Results

Variables	Quantile					Quantile				
	Q10	**Q25**	**Q50**	**Q75**	**Q90**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lctexppop (t-1)	-0.128**	-0.189***	-0.217***	-0.239***	-0.182***					
	(0.0499)	(0.0586)	(0.0613)	(0.0670)	(0.0536)					
lnlctimpop (t-1)						0.0207	-0.0819	-0.0369	-0.122	-0.185**
						(0.0771)	(0.0694)	(0.0916)	(0.0931)	(0.0777)
lngrppc (t-1)	-1.491	2.377	1.667	-1.723	-17.16***	-2.446	-1.169	1.236	-4.759	-5.497
	(5.2840)	(6.2060)	(6.4880)	(7.0950)	(5.6770)	(4.5120)	(4.0590)	(5.3590)	(5.4490)	(4.5430)
lngrppc2 (t-1)	0.0611	-0.0701	-0.0463	0.0882	0.661***	0.106	0.0654	-0.0291	0.203	0.246
	(0.1960)	(0.2300)	(0.2400)	(0.2630)	(0.2100)	(0.1650)	(0.1480)	(0.1950)	(0.1990)	(0.1660)
ifdipop (t-1)	-0.174***	0.0249	-0.0386	-0.0727	-0.0461	-0.289***	-0.0158	0.0622	-0.0806	-0.141**
	(0.0602)	(0.0707)	(0.0739)	(0.0809)	(0.0647)	(0.0573)	(0.0515)	(0.0680)	(0.0692)	(0.0577)
lnamtpop (t-1)	0.667***	0.415**	0.460***	0.335*	0.0637	0.481***	0.422***	0.320*	0.0922	0.128
	(0.1430)	(0.1670)	(0.1750)	(0.1910)	(0.1530)	(0.1420)	(0.1270)	(0.1680)	(0.1710)	(0.1430)
lnenergyconsp op (t-1)	0.484**	0.153	0.544**	0.948***	0.763***	0.345	0.359*	0.735***	1.323***	0.853***
	(0.2040)	(0.2400)	(0.2510)	(0.2740)	(0.2190)	(0.2110)	(0.1900)	(0.2510)	(0.2550)	(0.2130)
cityshare (t-1)	0.0181*	0.00585	0.00321	-0.0118	-0.0169*	0.0162	0.000615	-0.00548	-0.0173	-0.0238**
	(0.0092)	(0.0108)	(0.0113)	(0.0124)	(0.0099)	(0.0103)	(0.0093)	(0.0123)	(0.0125)	(0.0104)
Constant	8.442	-17.11	-11.71	10.74	115.5***	12.5	5.261	-10.27	30.05	34.82
	(35.2500)	(41.4000)	(43.2800)	(47.3400)	(37.8700)	(30.3700)	(27.3200)	(36.0800)	(36.6800)	(30.5900)
Observations	154	154	154	154	154	165	165	165	165	165
Pseudo R-sq	0.3311	0.2236	0.268	0.2899	0.3433	0.38	0.2489	0.240	0.2643	0.3539

Notation. Hereinafter *** indicates 1% significance level, ** indicates 5% significance level, * indicates 10% significance level. Standard errors are indicated in parentheses. Dummy variable for 2020 is included, but not reported.

Key Findings:

LCGs Exports & Emissions

- **Positive correlation**: Higher per capita **LCGs exports** in Russian regions are linked to **lower fuel combustion emissions**.
- Suggests **local production of LCGs** supports adoption and contributes to sustainable development.

LCGs Imports & Emissions

- **Tobit regression**: **Statistically insignificant** for LCG imports.
- **Quantile regression**: **Significant only at the 90th quantile**, indicating **imports play a minor role** in most regions.

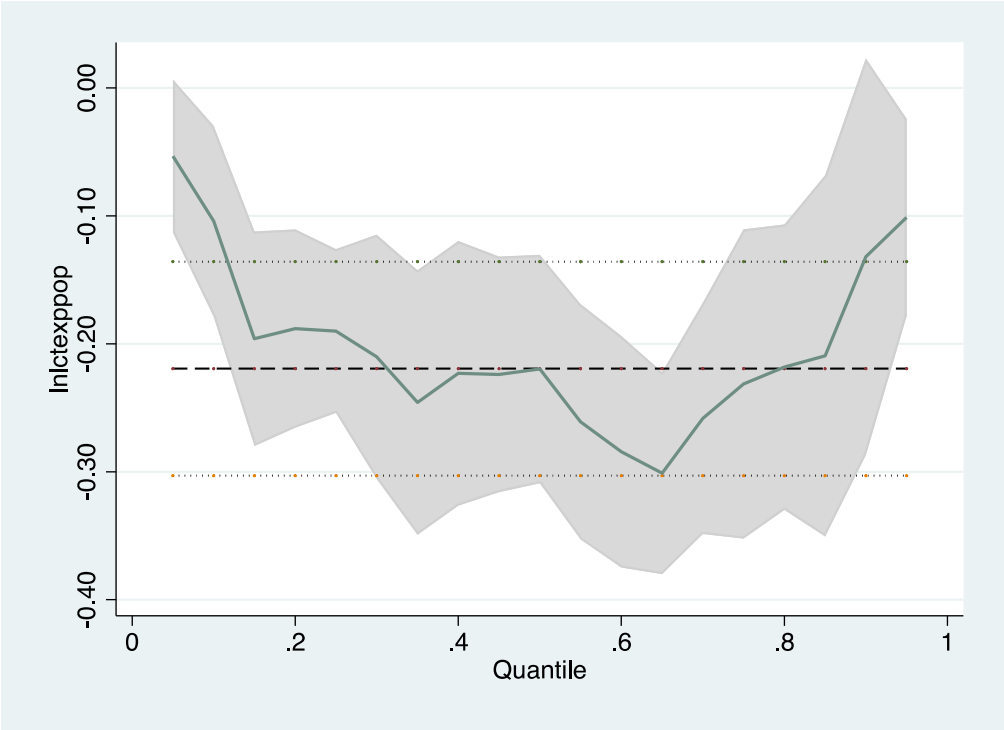
Advanced Technologies & Emissions

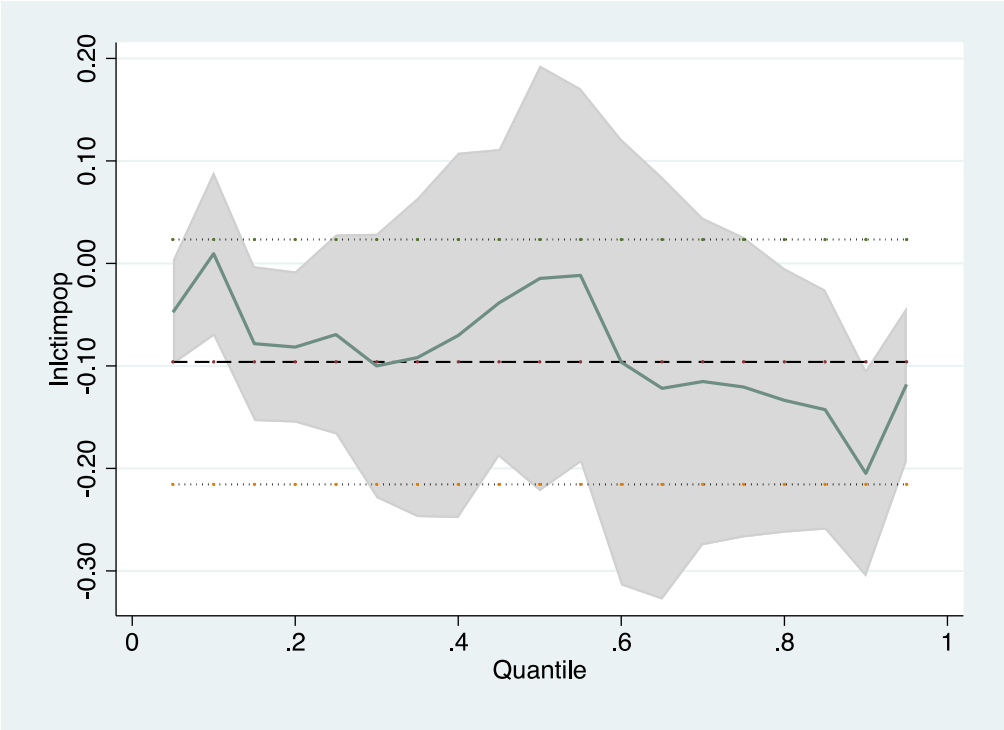
- **lnamtpop** (per capita use of advanced technologies) **positively associated** with **higher emissions** due to energy-intensive processes.

FDI & Emissions

- **Weak negative association** with emissions, significant only at certain quantiles in **quantile regression**.
- Implies **FDI** may promote **eco-friendly practices**.

Elasticity of LCGs Trade and Emission Reduction in Russian Regions





Elasticity of LCGs Exports

- **Negative relationship** between **per capita exports** of LCGs and **fuel combustion emissions**.
- **U-shaped pattern**: Peaks between the **50th and 80th quantiles**.

Elasticity of LCGs Imports

- **Negative relationship** between **per capita imports** of LCGs and **fuel combustion emissions**.
- Declines **monotonically** and becomes **statistically significant** only after the **90th quantile**.

Conclusions & Policy Implications

- **Regional Disparities in LCG Adoption**
  - **Significant variation** across Russian regions in LCG exports and imports.
  - Evidence of **inequalities** in the ability of regions to adopt **advanced technologies** and develop innovation capacities.
- **Non-Linear Relationship Between LCGs & Emissions**
  - **U-shaped correlation**: Low LCG export intensity has limited impact on emissions reduction, while high intensity shows diminishing returns due to **regional economic barriers**.
- **Policy Recommendations**
  - **Focus on lagging regions**: Transfer **best practices** from leading regions to improve performance.
  - **Support innovation**: Foster both **demand for efficient solutions** and **supply of promising technologies**.
  - **Promote LCG imports**: Enable imports in regions with **high emissions** to reach a threshold where they can significantly reduce emissions.
- **Tax Incentives & International Cooperation**
  - **Tax incentives** for companies investing in **high-cost foreign LCG technologies** to stimulate demand.
  - **Encourage international collaboration** to access **advanced low-carbon technologies** and facilitate **technology transfer**.
- **R&D & Infrastructure Investments**
  - **Targeted support for R&D** in regions with high potential for LCG innovation.
  - **Invest in infrastructure** to enhance regional participation in **global LCG trade**.

===>> A **multifaceted approach** is needed to bridge the technological gap across regions and position Russia as a key player in the **global low-carbon economy**.