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Disaggregating the Ecological Footprints of Trade in Pakistan

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Abstract
This study employs an ARDL model to examine the long- and short-run relationships between economic growth, trade in services, energy, and Pakistan's import ecological footprints, using time-series data from 1990 to 2022. The model demonstrates strong illustrative power, with an R-squared of 0.9865 and a low RMSE of 0.0071, emphasizing the accuracy of modeling Import Footprints. In the long run, the bio-capacity of imports emerges as a significant positive factor (coefficient = 1.2846, $p < 0.001$), revealing that imports with high bio-capacity demand, such as agricultural or forest products, are major contributors to the ecological footprint. Although GDP has a tad significant effect ($p = 0.059$), indicating potential efficiency gains in import production per GDP unit, energy consumption, inflation, and population effects remain statistically insignificant, suggesting that their environmental impacts may be channeled primarily through domestic production. In the short run, import bio-capacity continues to reveal a significant effect (coefficient = 1.0623, $p = 0.005$), highlighting that fluctuations in bio-capacity-intensive imports can immediately alter the ecological footprint. The results indicate that while trade in services and energy consumption show limited direct environmental impacts, managing imports with substantial bio-capacity needs is critical for sustainable trade policy. This analysis provides intuitions into the ecological implications of Pakistan's import composition and highlights the importance of aligning trade and environmental policy to manage long-term ecological footprints effectively.
Keywords: Ecological Footprints, Bio-capacity, Trade

1. Introduction
Pakistan's population has grown rapidly over the past decades, increasing demand for goods and services. As of 2023, Pakistan's population exceeds 240 million (PBS, 2023). It brings to bear immense pressure on the country's limited resources and infrastructure. This surge in demand has strained Pakistan's domestic production capacity, especially in essential sectors such as energy, food, and consumer goods, where local industries struggle to meet market needs. Subsequently, Pakistan has become heavily reliant on imports to fill the gap, particularly in food, machinery, chemicals, and petroleum products. This reliance on imports not only affects Pakistan's trade balance but also increases its ecological footprint, as imported goods often entail substantial resource use and emissions. The ecological footprint of trade is a significant factor in evaluating the environmental impact of global economic activities. Quantifying the environmental pressures exerted by a country's imports and exports offers insights into how trade affects natural resource usage, carbon emissions, and biodiversity in a broader perspective. For Pakistan, disaggregating the ecological footprint of trade has a unique relevance due to its resource-based exports, emerging industrial sector, and vulnerability to climate change. Understanding the ecological costs associated with trade can aid policymakers in designing sustainable trade policies that align with ecological limits and international climate obligations.

The concept of the ecological footprint provides a framework to assess the impact of human activities, such as trade, on ecological systems. Rees and Wackernagel (1996) pioneered the ecological footprint metric, which calculates the area of biologically productive land and water required to support a population's consumption levels and absorb its waste. In trade, ecological footprints encompass the resources used and emissions produced throughout the supply chains of exported and imported goods (Wiedmann et al., 2007). By isolating these ecological costs by sector, disaggregated footprint analysis reveals which industries contribute most to environmental degradation, informing targeted policies that could mitigate the negative impacts. Pakistan's trade, dominated by exports of agricultural products, textiles, and manufactured goods, has a diverse ecological footprint. Research shows that agriculture-based exports, such as rice and textiles, have significant water and land use footprints (Hassan et al., 2020). Industrial products, meanwhile, contribute to carbon emissions due to energy-intensive production processes. However, the environmental impact of imports, ranging from machinery to fossil fuels, also stresses Pakistan's ecological systems considerably. Disaggregating these impacts is essential to distinguish between domestic consumption and international demand-driven ecological pressures (Alam et al., 2022).

Unfortunately, Environmental policy integration within Pakistan's trade policies has remained limited in the past few decades. Yet, the need for accurate data and policy responses becomes urgent as global demand for sustainable production rises and Pakistan faces increased scrutiny over its environmental footprint. By detailing the ecological footprint of different trade sectors, Pakistan can better align its trade practices with international sustainability standards and manage ecological risks. Furthermore, such an approach can help Pakistan navigate global frameworks like the United Nations' Sustainable Development Goals (SDGs) and commitments under the Paris Agreement, particularly those related to responsible consumption, climate action, and life on land (United Nations,

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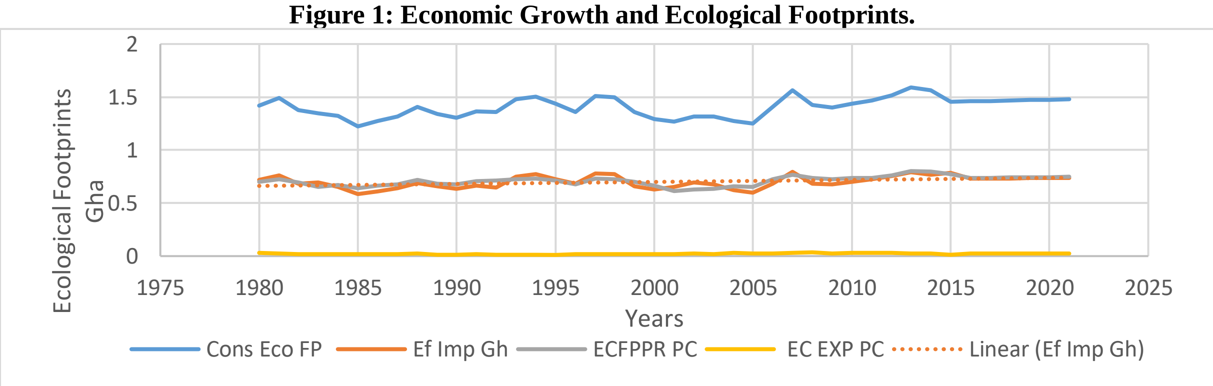
2015). The current paper is based on disaggregating the ecological footprint of trade in Pakistan and provides crucial comprehension for sustainable trade policy development by investigating the influencing factors of import footprints. This paper calculates the ecological footprints of Pakistan's Imports, using the product-specific footprints standards on the data provided by Pakistan's Economic Survey. This paper examines the short and long run relationship between the ecological footprints of imports and other important economic indicators, using the dynamic ARDL model. The author is interested in establishing that import footprints could be re-allocated by changes in GDP, energy use, population dynamics, and bio-capacity over time. Including the squared term of GDP, will help to understand the nonlinear nature of the relationship between economic growth and demand for cleaner imports.

1.1. Ecological Footprints by Economic Activity in Pakistan

Demand for natural resources across all sectors of the economy has an impact on environmental quality. Pakistan consumes a significant amount of natural resources over the year. To understand whether Pakistan Consumption Ecological Footprint (Cons Eco FP), depicted by the blue line in Figure 1, this metric is higher than the other indicators, consistently ranging between 1.2 and 1.6 Gha. This suggests that consumption activities in Pakistan have the largest impact on ecological footprints over the years. The fluctuations reflect varying levels of consumption over time, with peaks around the late 1990s and early 2000s. Ecological Footprints of Imports (Ef Imp Gh0), is denoted by the red line that shows the ecological footprints associated with imported goods. The values are relatively stable, lying between 0.5 and 0.8 Gha, with slight fluctuations over the years. The dotted red line (linear trend) shows a steady trend, indicating that the ecological impact of imports has remained constant over time without significant increases or decreases. EC EXP PC is the Ecological Footprint of Exports, symbolized by the purple line near the bottom; this metric is consistently low, close to zero. This indicates that the ecological footprint of exports is minimal compared to imports and consumption, suggesting that Pakistan's exports have a relatively small ecological impact on a global scale. ECFPPR PC is Production Ecological Footprint Per Capita, symbolized by the green line, this metric shows the ecological impact of production activities per capita. It is close to the values of imports, ranging from around 0.5 to 0.8 Gha, indicating that production activities are also a significant contributor to Pakistan's ecological footprint. However, it shows a fairly stable trend over the years, similar to the import trend. Consumption has the highest ecological footprint, indicating that domestic consumption is the primary driver of environmental pressure in Pakistan. Imports and production per capita also contribute notably to the ecological footprint, though they remain stable over time. Exports have a negligible ecological footprint, suggesting that the environmental impact of Pakistan's export activities is minimal compared to consumption and imports.

Figure 1: Economic Growth and Ecological Footprints.



2. Review of the Literature

2.1. Theoretical Literature on the Ecological Footprints of Trade

Examining the ecological footprints of trade requires an understanding of how international trade impacts resource consumption, emissions, and energy use over time (Rees, 1992). Import ecological footprints, in particular, capture the environmental burden associated with imported goods, which is an increasingly relevant concept as global trade intensifies and environmental sustainability comes to the forefront of economic policy debates. The concept of ecological footprints was first introduced by Rees (1992), who argued that economic activities, especially trade, could lead to environmental strain by consuming resources faster than ecosystems can regenerate. The ecological footprint framework assesses the environmental impact of human activities by measuring the land, water, and energy resources required for production and transport. Wackernagel et al. (2002) further expanded this framework, emphasizing the role of ecological footprints in national accounting to assess the environmental sustainability of countries and their trade practices.

Dietz and Rosa (1994) developed the IPAT model (Impact = Population x Affluence x Technology) to analyze the environmental impact of economic growth and population changes. This model highlights that increases in both economic growth and population size can lead to higher ecological footprints if resource use is not managed sustainably. York, Rosa, and Dietz (2003) further analyzed how modern economic activities, particularly trade, amplify ecological footprints by consuming extensive resources. They posited that as economies grow, their ecological footprint tends to increase due to heightened demand for energy and material resources, which, if left unchecked, leads to environmental degradation. Suri and Chapman (1998) examined the link between trade, energy consumption, and environmental sustainability, finding that higher energy consumption leads to larger ecological footprints, especially in economies that are dependent on fossil fuels. Lenzen, Dey, and Foran (2004) extended this research, noting that the energy demands of households and businesses are significant contributors to a country's ecological footprint. This is particularly relevant in economies with high-energy imports or exports, where the ecological burden is intensified by energy demands (Dietz, Rosa, & York, 2007). As environmental awareness grew, Ewing et al. (2010) provided a comprehensive framework for calculating national ecological footprints, which underscores the role of imports in environmental sustainability. They emphasized that countries relying heavily on imports often experience increased ecological strain as they import goods produced with environmentally harmful practices. Giljum, Hubacek, and Sun (2007) analyzed this issue in the context of developing economies, where the lack of sustainable resource management further amplifies the ecological footprint associated with trade. Tilton (1996) argued that inflation indirectly influences ecological footprints by altering demand for imported goods. Higher inflation can reduce purchasing power, potentially decreasing import demand, while low inflation may encourage imports, raising ecological footprints. Stern (2004) critiqued the Kuznets curve hypothesis, which posits that economic growth initially worsens environmental degradation before improvements set in. His research indicated that environmental improvements depend heavily on sustainable economic practices, challenging the assumption that growth alone leads to environmental gains. Wiedmann et al. (2006) and more recent studies by York et al. (2011) examined how a shift toward services, particularly digital trade, could reduce ecological footprints. This approach suggests that economies focusing on less resource-intensive activities, such as information technology and financial services, can achieve economic growth with a reduced environmental burden. Wiedmann and Barrett (2010) further explored how input-output analysis can allocate ecological footprints to consumption categories, showing that consumption patterns, rather than just production, play a crucial role in determining ecological footprints. From the 2010s onward, research has increasingly focused on quantifying ecological footprints across sectors, aiming to support sustainable policy decisions. Wiedmann and Lenzen (2018) emphasized the need for policy frameworks that consider both local and global ecological footprints in trade. More recently, research by Li and Zhang (2022) has highlighted the role of bio-capacity constraints in determining ecological footprints, particularly in developing countries like Pakistan, where limited resources and rapid economic growth intensify the ecological burden of imports. These studies underscore the importance of incorporating environmental considerations into trade policies to ensure sustainable economic growth.

2.2. Empirical Literature on Ecological Footprints and Economic Growth

Research on ecological footprints and environmental sustainability has gained significant attention globally, with a growing focus on the economic activities contributing to environmental degradation. Studies from both developed and developing countries, including Pakistan, have examined the intricate relationships between trade, energy consumption, industrial growth, and ecological footprints. This literature highlights the global challenge of achieving sustainable economic growth while mitigating environmental impacts, with specific relevance to policy reforms and sustainability efforts in developing countries like Pakistan. The relationship between economic growth and carbon footprints has been a subject of extensive research. Khan, and Athar (2017) explored the impact of income growth on the carbon footprints of production in Pakistan, finding that increased income drives up carbon emissions due to the country's dependence on fossil fuels. This study highlights the environmental trade-offs associated with economic growth in developing nations. Similarly, in a study on China, Wang et al. (2018) employed a panel data model and found that economic expansion, particularly in industrial sectors, significantly increases carbon emissions. Trade, especially in energy-intensive goods, has a significant effect on ecological footprints. Farooq and Chani (2018) found that trade liberalization in Pakistan leads to a higher ecological footprint due to increased imports of goods that contribute to environmental degradation. This finding aligns with global studies, such as by Stiglitz (2002), who argued that trade liberalization often results in greater ecological degradation due to higher resource use. A study by Choi et al. (2020) on trade and environmental degradation in South Korea found a positive association between trade openness and carbon emissions, especially in the context of importing energy-intensive products. These studies suggest that trade policies should incorporate environmental considerations to reduce the ecological footprint. Energy consumption remains one of the largest contributors to ecological footprints, particularly in energy-intensive economies. Ali and Malik (2015) used the ARDL model to assess the relationship between energy consumption and ecological footprints in Pakistan, concluding that energy use, especially fossil fuel consumption is positively correlated with ecological degradation. This relationship is consistent with findings from other regions, such as in India, where Kumar and Agarwal (2019) demonstrated that increasing energy consumption from non-renewable sources significantly raises the country's ecological footprint. This points to the urgent need for renewable energy adoption to curb ecological degradation. Industrialization, a key driver of economic growth, significantly influences ecological footprints. In a study on industrialization's impact in Brazil, Silva et al. (2021) found that rising industrial activity led to a significant increase in ecological footprints, particularly in terms of carbon emissions. Similarly, The study emphasizes the need for cleaner industrial practices and energy-efficient technologies to reduce ecological footprints. Khan, and Athar (2017) introduced novel econometric methods to estimate the factors influencing Pakistan's ecological footprint using the STIRPAT model. Their study suggests that population growth, economic affluence, and technology significantly contribute to ecological degradation. Internationally, similar models have been applied to other countries, such as in the United States (Dietz et al., 2007), where the STIRPAT framework was used to identify drivers of ecological degradation, underscoring the importance of technological and policy interventions to mitigate environmental harm.

After studying all these papers, the author is of the view that achieving sustainable development in Pakistan and globally requires integrating environmental considerations into economic and trade policies, promoting energy efficiency, and adopting cleaner industrial technologies. The global literature and studies from Pakistan emphasize the interconnectedness of trade, energy consumption, and economic growth in shaping ecological footprints and underscore the importance of transitioning towards more sustainable practices.

3. Materials and Methods

3.1. Data

The data for the variables LGDP, Population, Energy Consumption, Inflation CPI, and Trade in Services are sourced from the World Bank database, covering the period from 1991 to 2022. This dataset includes key economic indicators and environmental data, which are widely used for understanding the relationship between economic growth and environmental sustainability. However, for Import Footprints and Import Bio-capacity, the data has been specifically calculated by the author, using the approach of Khan, and Athar (2017) The Import Footprints and Import Bio-capacity are derived based on imports by goods from the Economic Survey of Pakistan. These data sets are estimated using ecological footprint and biological capacity standards for various products, as outlined in studies by researchers and international organizations. (See Appendix: for details). These calculations incorporate product-specific ecological footprint standards to assess the environmental impact of imports in Pakistan, ensuring a more accurate representation of ecological pressures driven by international trade.

3.2. Methodology

In this paper, the ARDL model approach is applied after ensuring that the variables are stationary or integrated of order one (I (1)) or zero (I (0)), using the Dickey-Fuller test, as presented in Table 4.2. Variables that are I (0) are used in their level form, while those integrated of order I (1) are differenced before being included in the model. The optimal lag length for each variable is selected based on criteria such as the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). Specifically, the ARDL (1,0,0,0,0,1,1) model is employed, which includes 1 lag for the dependent variable (Import Footprints), no lags for the explanatory variables (Import Bio-capacity, LGDP, Population, Energy Consumption, and Inflation CPI), and 1 lag for Trade in Services. The lag structure is determined based on the dynamics of the data and model selection criteria. After selecting the appropriate lag structure, the ARDL equation is estimated for both the short-run and long-run relationships. To assess co-integration, the Bounds Testing Approach by Pesaran et al. (2001) is applied, where the F-statistic and t-statistic values help determine whether a long-term relationship exists among the variables. In addition, diagnostic tests for serial correlation, heteroscedasticity, and normality are performed to ensure the model's validity, confirming that the residuals are free from autocorrelation, exhibit constant variance, and follow a normal distribution.

3.2.1. Study Model

The general form of the model

$$Yt = A + B\sum Yt - i + BXt + B\sum Xt - i + Ut \quad (1)$$

Yt is the dependent variable and A is the intercept

Yt-i is the lagged dependent variable

Xt is the independent variable,

Xt-i is the lagged independent variable

Ut is the error term

3.2.1.1. Auto Regressive Distributive Lag Model (ARDL)

$$\Delta IMFP_t = \propto + \sum_{i=1}^{n} \beta_{1i} \Delta IMFP_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta IMBC_{1t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta LGDP_{2t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta ENC_{3t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta POP_{5t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta Inf_{6t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta TrS_{5t-i} + \delta_1 IMFP_{t-1} + \delta_2 IMBC_{1t-1} + \delta_3 LGDP_{2t-1} + \delta_4 ENC_{3t-1} + \delta_5 POP_{4t-1} + \delta_5 Inf_{4t-1} + \delta_6 TrS_{5t-1} + \varepsilon_t \quad (2)$$

- Δ shows change
- $\sum_{i=1}^{n} \beta_{1i} \Delta$ short-run dynamics
- $\propto$ is constant
- δ long run dynamics
- ε_t error

4. Results and Discussion

4.1. Descriptive Statistics of Important Variables

The average Import Footprint value of 0.70875 with a low standard deviation (0.0504) suggests relatively stable environmental impacts per unit of imported goods over the observed period. This also reflects the ecological load or carbon emissions that imports generate, which point to resource dependency and the environmental impact of trade. The mean of 5.40625 with a narrow range (5.23 to 5.54) suggests a relatively consistent capacity for local ecosystems to provide resources or absorb waste from imports. In economic terms, this stability indicates an ability to sustain certain levels of import-driven consumption without overtaxing bio-capacity. However, the close clustering around the mean suggests a limited buffer if import rates or environmental loads increase. Results show that this measure reflects sustained economic output with an average of 11.16156 and low variation (0.3099). A higher LGDP generally implies a developed or growing economy, with moderate dispersion indicating consistent economic growth over time. Economic theory would expect LGDP to positively correlate with imports and energy consumption, as growth typically drives higher demand for both domestic and imported goods.

Population growth usually has significant implications for consumption patterns, demand for resources, and environmental pressures, which can affect Import Footprints and Bio-capacity, linking directly to environmental economics. Energy consumption has a higher mean (48.41844) and a relatively large spread (4.2762), reflecting significant variation in energy demand. Inflation shows considerable variability, with a mean of 8.82375 and a high standard deviation of 4.4322. This indicates fluctuations in the general price level, which can influence both domestic and imported goods' affordability. High inflation may discourage imports or shift demand to less costly or domestically produced goods, while low inflation could encourage higher import levels, depending on relative price changes in the global market. Trade shows a mean value of 6.06625 and a broader range, Trade in Services reflects the economy's engagement in non-physical transactions. Economic theory suggests that as economies grow, service trade often increases, supporting less resource-intensive growth. Thus, a higher trade in services is generally favorable for sustainable growth, as it can potentially reduce Import Footprints by focusing on intangible exports over resource-intensive imports.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std.dev.	Min	Max
Import Footprints	32	0.70875	0.050402	0.6	0.79
Import Biocapacity	32	5.40625	0.091783	5.23	5.54
LGDP	32	11.16156	0.309923	10.66	11.57
Population	32	8.243125	0.089782	8.08	8.37
Energy consumption	32	48.41844	4.27624	41.19	58.1
Inflation Cpi	32	8.82375	4.432224	2.53	20.29
Trade in services	32	6.06625	1.475916	3.49	8.68

4.2. Pre-Estimation Test Results

The Dickey-Fuller test results at the level form suggest that none of the variables are stationary at conventional significance levels (1%, 5%, or 10%). The Z(t) test statistics for Import Footprints, Import Biocapacity, LGDP, Population, Inflation CPI, and Trade in Services do not exceed the critical values in magnitude, indicating the presence of unit roots in these variables. Energy Consumption comes close to the 5% significance level but does not meet the threshold, implying that all variables require differencing to achieve stationarity and avoid spurious regression. All variables exhibit non-stationarity in their level form, as indicated by Z(t) test statistics that do not exceed the critical values at any conventional significance level. This implies the presence of unit roots across variables, which suggests that they follow stochastic trends. Consequently, these variables need to be differenced to achieve stationarity. Differencing will allow for a more robust analysis by eliminating time-dependent trends and reducing the risk of spurious regression results.

Table 2: Unit root test Dickey-Fuller test results

Dickey-Fuller at (level)				
variable name	Z(t) Test statistic	1%	5%	10%
Import Footprints	0.04	-2.65	-1.95	-1.602
Import Biocapacity	1.658	-2.65	-1.95	-1.602
LGDP	3.709	-2.65	-1.95	-1.602
Population	11.614	-2.65	-1.95	-1.602
Energy consumption	-2.489	-2.65	-1.95	-1.602
Inflation Cpi	-0.488	-2.65	-1.95	-1.602
Trade in services	-1.188	-2.65	-1.95	-1.602

4.3. Bound test results

The ARDL Bounds Test results indicate a statistically significant long-run relationship (cointegration) among the variables. The F-statistic of 9.450 exceeds the upper bound critical values at all significance levels (with a 1%

upper bound of 4.43), leading to a rejection of the null hypothesis of no levels relationship. Similarly, the t-statistic of -7.462 is below the critical values' lower bound, further supporting cointegration. Thus, strong evidence suggests a long-term equilibrium relationship exists among the variables in the model.

Table 3: Bound test

F-Statistic Critical Values (Case 3)		
Significance Level	I(0) (Lower Bound)	I(1) (Upper Bound)
10% (L_1)	2.12	3.23
5% (L_05)	2.45	3.61
2.5% (L_025)	2.75	3.99
1% (L_01)	3.15	4.43
F-statistic: 9.450		
Decision Rule:		
Accept if F < critical value for I(0) regressors.		
Reject if F > critical value for I(1) regressors.		
t-Statistic Critical Values (Case 3)		
Significance Level	I(0) (Lower Bound)	I(1) (Upper Bound)
10% (L_1)	-2.57	-4.04
5% (L_05)	-2.86	-4.38
2.5% (L_025)	-3.13	-4.66
1% (L_01)	-3.43	-4.99
t-statistic: -7.462		
Decision Rule:		
Accept if t > critical value for I(0) regressors.		
Reject if t < critical value for I(1) regressors.		

4.4. Long Run and Short Relationships

The ARDL model reveals a strong fit, with an R-squared of 0.9865 and an Adjusted R-squared of 0.9801, indicating that the model explains nearly 98% of the variation in Import Footprints. This high explanatory power, along with a low Root Mean Squared Error (RMSE) of 0.0071 and a robust Log-likelihood of 108.51, suggests an accurate and well-fitted model. The lagged Import Footprints coefficient (-0.35666) indicates moderate adjustment speed; however, its lack of statistical significance (p = 0.112) suggests that deviations from long-term equilibrium in Import Footprints are not strongly corrected in the short run.

In the long-run results, Inflation (CPI) and Population have non-significant impacts (p = 0.762 and p = 0.136, respectively) on Import Footprints. This aligns with the idea that inflationary pressures and population dynamics may have indirect effects on ecological or environmental imports, influencing them through channels not captured in this model. However, LGDP shows a borderline significant effect (p = 0.059) with a negative coefficient (-1.02533), suggesting that as GDP rises, import footprints may decrease slightly. This could theoretically reflect greater efficiency or innovation in production processes that reduce environmental impact per unit of GDP, although the effect lacks strong statistical backing.

Energy Consumption shows a positive association but remains statistically insignificant (p = 0.245). Energy use could drive up ecological imports through higher demand for energy-intensive goods, but the non-significance here might indicate that energy consumption affects the environment primarily through domestic production rather than imports. Import Bio-capacity has a strong positive and significant long-run effect (coefficient = 1.2846, p < 0.001), suggesting that as the bio-capacity associated with imports increases, so does the import footprint. This result highlights a critical linkage: imports with high bio-capacity demand, like those from agriculture or forest products, exert a substantial environmental impact, especially over the long term. It underscores how trade patterns reliant on bio-capacity-rich imports can drive up the ecological footprint of an economy. Trade in Services also shows a positive coefficient but is statistically non-significant (p = 0.207), possibly indicating that the ecological impact of trade in services is limited compared to trade in physical goods.

In the short run, D1 Import Bio-capacity has a significant positive effect (coefficient = 1.0623, p = 0.005), showing that short-term changes in import bio-capacity significantly impact Import Footprints. This supports the idea that fluctuations in bio-capacity-intensive imports can immediately impact environmental footprints, reflecting the responsiveness of ecological imports to shifts in demand for natural resources. However, D1 Trade in Services has a small, non-significant negative impact (p = 0.142), suggesting that short-term changes in service trade do not substantially affect ecological imports. This finding underscores the environmental importance of managing imports with high bio-capacity demands, as they significantly affect the ecological footprint of trade. While GDP shows a potential influence, its effect is less certain, and energy consumption appears to impact domestic environmental metrics more than imports. This analysis sheds light on the importance of bio-capacity in trade policy, particularly regarding sustainable resource use and reducing ecological footprints over time.

Table 4.4 ARDL Long run and short run estimates

ARDL (1,0,0,0,0,1,1) regression

R-squared = 0.9865
Adj R-squared = 0.9801
Root MSE = 0.0071
Log-likelihood = 108.51153

D. Import Footprints	Coefficient	Std. err.	t	P>t	[95% conf.	interval]
		ADJ				
Import footprints						
L1.	-0.35666	.2138241	-1.67	0.112	-.804198	0.09088
		Long Run				
Inflation CPI	-0.00033	.0010647	-0.31	0.762	-.0025551	0.001902
LGDP	-1.02533	.2890476	-0.28	0.059	-.7117126	1.161045
Population	-0.74487	.4787967	-1.56	0.136	-1.747003	0.257263
Energy Consumption	0.003556	.0029627	1.20	0.245	-.0026445	0.009757
L import Biocapacity	1.284592	.2016057	6.37	0.000	.8626265	1.706558
L Trade in services	0.040465	.0310033	1.31	0.207	-.024426	0.105355
		Short Run				
L Import biocapacity						
D1.	1.062325	.3314523	3.21	0.005	.3685874	1.756063
L Trade in services						
D1.	-0.01739	.011353	-1.53	0.142	-.0411526	0.006372
Cons	-0.02867	.9350153	-0.03	0.976	-1.98568	1.928339

5. Conclusion

This study investigates the ecological footprint of Pakistan's imports using a dynamic ARDL model to assess both short- and long-term relationships with key economic indicators. With a population now exceeding 240 million, Pakistan’s high import dependency is driven by demand that strains its limited production capacity, particularly in critical sectors like energy, food, and consumer goods. This reliance on imports exacerbates trade imbalances and contributes significantly to Pakistan's ecological footprint, with far-reaching environmental implications.

The ARDL model offers a robust explanation, capturing 98% of the variation in Import Footprints, with an R-squared of 0.9865 and a low RMSE of 0.0071, signaling a well-fitted model. In the long run, the results reveal a significant positive relationship between Import Bio-capacity and Import Footprints, indicating that imports of bio-capacity-intensive goods, such as agricultural and forest products, are major contributors to Pakistan’s ecological impact. Conversely, the non-significant long-term relationships for Inflation, Population, and Energy Consumption suggest indirect effects on import footprints, hinting that these variables may influence ecological outcomes through alternative mechanisms. Energy Consumption shows a positive but statistically insignificant association with Import Footprints, which implies that energy usage, while a critical factor in domestic environmental impact, may have less direct influence on the ecological footprint of imports. This finding could reflect the fact that Pakistan's energy consumption primarily affects domestic production footprints rather than the environmental impacts of imported goods. Nonetheless, as energy-intensive sectors expand, they may increase demand for energy-intensive imports, thereby indirectly affecting the ecological footprint over time. The insignificant effect may also indicate opportunities for policies aimed at reducing the carbon intensity of energy use within the import supply chain, which could yield environmental benefits. In the short run, Import Bio-capacity shows a significant positive effect, indicating that immediate changes in bio-capacity-intensive imports directly impact Pakistan’s ecological footprint. The insignificance of Trade in Services in both the short and long run suggests that the environmental impact of service imports is minimal compared to physical goods, which tend to have higher bio-capacity and resource demands. However, as Pakistan’s trade in services expands, particularly in technology and finance, its relatively lower environmental footprint compared to manufacturing and energy-intensive imports could represent a pathway for more sustainable economic growth.

In conclusion, the author establishes that this research underscores the critical importance of integrating ecological considerations into Pakistan’s trade policies. Disaggregating ecological impacts by import type reveals that policies targeting bio-capacity-intensive imports and encouraging energy efficiency are vital to mitigating Pakistan’s overall ecological footprint. By aligning trade practices with sustainable development goals, Pakistan can meet international commitments, such as the United Nations' SDGs and the Paris Agreement, while managing ecological risks more effectively. Sustainable trade policy should prioritize efficient resource management and seek to capitalize on the relatively low ecological footprint of service trade to balance economic growth with environmental sustainability.

6. Policy Recommendations

Given the significant impact of bio-capacity-intensive imports (e.g., agricultural and forest products) on Pakistan's ecological footprint, policies should encourage sustainable sourcing of these goods. Pakistan could implement stricter environmental standards and certification requirements for imports with high bio-capacity demands. Additionally, promoting partnerships with countries that maintain sustainable production practices can help reduce the ecological footprint associated with these imports, aligning with global sustainability standards and reducing resource strain.

While energy consumption does not have a significant direct impact on import footprints, improving domestic energy efficiency can reduce indirect pressures for energy-intensive imports, which contribute to environmental degradation. Policies to upgrade industrial energy standards, offer tax incentives for adopting green technology, and invest in renewable energy sources could reduce reliance on fossil fuel imports and lower the carbon footprint of imported goods. By reducing the energy intensity of domestic industries, Pakistan can mitigate both domestic and imported environmental impacts over time. Service trade is showing minimal impact on ecological footprints compared to physical goods; Pakistan should leverage the relatively low environmental footprint of its expanding service sector. Policies could support the growth of service exports in IT, finance, and professional services, which require fewer natural resources and energy compared to manufacturing or agricultural trade. Incentives for skill development in the services sector, along with investment in digital infrastructure, can help Pakistan shift towards an economy that is less ecologically demanding and more sustainable. Developing a comprehensive green trade policy framework can provide guidelines for sustainable imports and exports, encouraging trade practices that consider ecological costs. Additionally, Pakistan could set up monitoring systems to track the ecological footprint of imports and exports, helping policymakers make informed decisions and evaluate the effectiveness of environmental policies over time.

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