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KEYWORDS

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Findings reveal significant heterogeneity across Italian provinces: regions like Aosta, Bergamo, and Brescia exhibit strong green specialization, while areas such as Turin, Rome, and Catanzaro are more reliant on vulnerable, high-emission industries. These insights inform policy recommendations tailored to regional contexts. For provinces with high green specialization, policies should enhance competitive advantages through investment in research and development, subsidies for green innovation, and support for sustainable operations.
Conversely, regions with high vulnerability, particularly in Southern Italy, require strategies focused on economic diversification and a transition away from fossil fuel-dependent industries, including investments in renewable energy projects. Provinces with dual specialization necessitate balanced approaches that manage the decline of vulnerable sectors while fostering green industry growth, such as retraining workers and supporting SMEs in innovation. The study emphasizes the necessity of a coherent national strategy to complement regional efforts, ensuring equitable resource

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Opportunities and challenges for the green industry: specializations of the Italian provinces and implications for the industrial energy policies

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Abstract

This study examines regional variations in Italy's green industry specialization and their implications for energy and industrial policies. Utilizing the Taxonomy Alignment Coefficient (TAC) and Taxonomy Exposure Coefficient (TEC), the research assesses the alignment of provincial sectors with low-carbon economies and their dependence on fossil fuels, respectively. Findings reveal significant heterogeneity across Italian provinces: regions like Aosta, Bergamo, and Brescia exhibit strong green specialization, while areas such as Turin, Rome, and Catanzaro are more reliant on vulnerable, high-emission industries. These insights inform policy recommendations tailored to regional contexts. For provinces with high green specialization, policies should enhance competitive advantages through investment in research and development, subsidies for green innovation, and support for sustainable operations. Conversely, regions with high vulnerability, particularly in Southern Italy, require strategies focused on economic diversification and a transition away from fossil fuel-dependent industries, including investments in renewable energy projects. Provinces with dual specialization necessitate balanced approaches that manage the decline of vulnerable sectors while fostering green industry growth, such as retraining workers and supporting SMEs in innovation. The study emphasizes the necessity of a coherent national strategy to complement regional efforts, ensuring equitable resource distribution and

reducing North-South disparities. Adaptive policies, responsive to technological and market evolutions, are crucial, as is collaboration between public and private sectors to drive innovation and inclusive growth. By addressing regional specificities and promoting innovation, Italy can effectively navigate the green transition and position itself as a leader in global sustainability efforts.

Keywords: Green industry; Green transition; Industrial policy; Energy policy; Regional specialization; Taxonomy Alignment Coefficient (TAC); Taxonomy Exposure Coefficient (TEC); Italian provinces.
JEL Codes: Q56, Q48, L52, R11, F14

1. Introduction

The rapid evolution of the green industry represents both a significant opportunity and a formidable challenge for modern economies, particularly for countries like Italy that are deeply entrenched in traditional industrial practices. As the world increasingly acknowledges the urgent need for sustainable development, the concept of a "green industry" has gained prominence, driving both scientific research and policy discussions at national and international levels. However, despite the growing focus on this sector, there remains a lack of consensus on what exactly constitutes a green industry and how to measure its impact effectively.

This study aims to bridge this gap by offering a comprehensive analysis of Italy's provincial specializations in relation to the green industry. By focusing on Italy's provinces, this research seeks to identify which regions are best positioned to lead the green transition and which may be at risk due to their dependence on industries that could become obsolete in the shift toward sustainability. The goal is not only to map out the current landscape of green and vulnerable sectors across Italy but also to provide actionable insights that can inform energy and industrial policies aimed at facilitating the transition to a sustainable economy.

The objectives of this study are threefold. First, it seeks to define and measure green industries by utilizing a sector-based approach that incorporates recent academic and policy-driven research. Second, the study aims to develop and apply specialized indices of provincial export specialization that highlight regions with significant green exports or those vulnerable to the transition. Third, the study intends to create a taxonomy of Italian provinces based on their potential to either drive or be threatened by the green transition, offering a clear framework for policymakers.

In this study, we employ the Taxonomy Alignment Coefficient (TAC) and Taxonomy Exposure Coefficient (TEC) developed by Alessi and Battiston (2022) as foundational tools to assess the green and vulnerable industries across Italy's provinces. The decision to utilize this taxonomy is

driven by its comprehensive and nuanced approach to categorizing industries based on their alignment with sustainability goals and their vulnerability to the green transition. The TAC measures the extent to which a sector's activities are aligned with the objectives of a low-carbon economy, such as through the adoption of renewable energy and energy-efficient technologies, while the TEC assesses the degree of a sector's dependence on fossil fuels and other high-emission activities, which render it vulnerable in the face of regulatory and market shifts towards sustainability. By applying this dual-coefficient framework, we are able to capture the complex and often overlapping nature of industrial specialization, providing a granular and accurate assessment of the economic landscape as it relates to the green transition. This methodology not only allows us to identify regions that are well-positioned to thrive in a sustainable future but also highlights those that may face significant challenges, thereby offering valuable insights for targeted policy interventions.

To achieve these objectives, the research is guided by several key questions:

How can green industries be effectively defined and measured at the provincial level in Italy?

Which Italian provinces are most specialized in green exports, and what are the implications for their role in the green transition?

Which provinces are at risk of economic decline due to their specialization in industries that are vulnerable to the green transition?

How can industrial policies be tailored to support regions that are well-positioned to lead the green transition, as well as those that may struggle to adapt?

By addressing these questions, the study provides a detailed understanding of the provincial distribution of green and vulnerable industries in Italy. This understanding is crucial for developing targeted industrial policies that can support the green transition in a way that is both economically and socially sustainable. Ultimately, the research aims to contribute to the broader discourse on how regions can navigate the complex process of structural change required to achieve long-term sustainability.

2. Outline of literature background

The concept of the green industry has gained significant traction in recent years, driven by the pressing need to address environmental challenges while sustaining economic growth. As governments, businesses, and international organizations increasingly recognize the importance of transitioning to sustainable practices, the definition and scope of green industries have become central to discussions in both academic and policy circles. However, despite the growing consensus on the necessity of green industries, there remains considerable debate over how to define and measure them effectively.

Green industries are generally understood as sectors that contribute to environmental sustainability through the reduction of carbon emissions, the efficient use of resources, and the adoption of clean technologies. The International Labour Organization (ILO) has long emphasized the potential of green jobs in promoting decent work within a sustainable economy (ILO, 2008). Similarly, the United Nations Industrial Development Organization (UNIDO) frames green industry as a critical component of sustainable development, highlighting its role in fostering environmentally responsible investments (UNIDO, n.d.). However, as noted by Salvatelli (2014), the absence of a universally accepted definition complicates efforts to identify green sectors, leading to inconsistencies in both research and policy implementation.

Different approaches have been developed to classify and measure green industries. One widely referenced framework is the U.S. Bureau of Labor Statistics (BLS) classification of Green Jobs, which identifies sectors based on their contribution to environmental sustainability, either through the production of green goods and services or the adoption of green processes (U.S. Bureau of Labor Statistics, n.d.). This sectoral approach provides a foundational method for identifying and categorizing green industries but does not fully capture the complexities of the global green economy.

The Environmental Goods and Services Sector (EGSS), as defined by Eurostat, offers a broader classification system that includes industries directly involved in environmental protection and resource management (Eurostat, n.d.). This framework is complemented by the System of Environmental-Economic Accounting (SEEA), which integrates environmental data with economic accounts to better identify and measure green sectors (SEEA, 2019). These methodologies represent significant strides in the effort to standardize the classification of green industries, though challenges remain, particularly in adapting these frameworks to different regional contexts.

Technological advancements have introduced innovative methods for identifying green industries. For example, text mining techniques are increasingly used to detect green companies based on corporate descriptions and patent classifications, providing a dynamic understanding of the green industry landscape (Shapira, Gök, Klochikhin, & Sensier, 2014). These methods enable real-time analysis and are particularly useful for identifying emerging sectors within the green economy.

The literature underscores the critical role of green industries in the global transition towards sustainability. According to the International Energy Agency (IEA), the clean energy sector alone employs over 50% of the global energy workforce, highlighting the economic importance of green industries (IEA, 2022). Allan, Lewis, and Oatley (2021) argue that green industrial policy is central to the global transformation of climate politics, emphasizing that green industries can drive both environmental and economic progress.

The European Union's Green Deal and its accompanying Green Deal Industrial Plan further illustrate the strategic importance of green industries in shaping Europe's economic future (Leonard, Pisani-Ferry, Shapiro, Tagliapietra, & Wolff, 2021). These initiatives aim to integrate

green industries into the broader economic framework to ensure that the transition to a low-carbon economy is both equitable and effective. The European Commission has also highlighted the importance of maintaining open trade and resource accessibility to support green industries, as articulated in its recent Green Deal Industrial Plan for the Net-Zero Age (Commissione Europea, 2023).

Despite the growing emphasis on green industries, measuring their impact and effectiveness remains a significant challenge. The lack of standardized metrics and the inherent complexity of categorizing industries across different sectors and regions contribute to these difficulties. Bowen, Park, and Elvery (2013) highlight the diversity within green industries, ranging from renewable energy and clean transportation to waste management and sustainable agriculture, which necessitates tailored approaches to both measurement and policy design.

Recent contributions to the literature, such as those by Barbieri, Marzucchi, and Rizzo (2023), emphasize the interdependencies between green technologies and traditional sectors, suggesting that a comprehensive industrial policy must account for these relationships. Furthermore, Barbieri et al. (2022) explore regional technological capabilities and green opportunities in Europe, providing insights into how different regions can capitalize on their existing strengths to advance the green transition.

In the Italian context, the discourse on green industries is shaped by the country's unique industrial landscape and its role within the broader European framework. Studies by Di Tommaso et al. (2020, 2022, 2023) highlight the importance of a systemic approach to green transition, which integrates economic, social, and environmental dimensions. Italy's regional disparities, particularly between the industrial North and the less developed South, present both challenges and opportunities for the development of green industries.

The Italian experience underscores the need for tailored industrial policies that reflect regional specializations and varying capacities to adapt to the green transition. Ferrannini et al. (2021) emphasize the role of industrial policy in achieving sustainable human development in the post-Covid-19 era, arguing that targeted interventions are necessary to support regions in transitioning to green industries.

In conclusion, the literature on green industries presents a complex and evolving field that blends various definitions, methodologies, and case studies to illustrate the multifaceted nature of this sector. While significant progress has been made in understanding and promoting green industries, challenges remain in standardizing definitions, measuring impact, and ensuring that the benefits of the green transition are widely shared. This study builds on these foundations, applying a sector-based approach to analyze green and vulnerable industries across Italy's provinces, aiming to provide actionable insights for policymakers and contribute to the broader discourse on sustainable development.

3. Data and descriptive statistics

To understand the current landscape of green and vulnerable industries across Italy's provinces, it is essential to begin with a thorough examination of the data, including territorial references, time coverage, and sources. Additionally, descriptive statistics such as maps, figures, and tables provide a clear and comprehensive view of the spatial distribution and characteristics of these industries.

The analysis in this study is conducted at the provincial level, which allows for a detailed exploration of regional disparities and industrial specializations within Italy. Italy's 107 provinces represent distinct administrative divisions within the country's regions, each varying significantly in terms of economic structure, industrial capacity, and development levels. By focusing on these provinces, the study captures the heterogeneity across different areas, offering a nuanced understanding of how green industries are distributed and which regions are most vulnerable to economic shifts driven by the green transition. This provincial-level analysis is particularly important in Italy due to the well-documented economic differences between the industrial North and the less developed South, a dichotomy that has long been a focus of both economic and policy research.

The time coverage for the data used in this study centers on the year 2019, a critical period for analyzing trends and shifts in green and vulnerable industries within Italy. The year 2019 is selected because it represents a relatively stable economic environment before the global disruptions caused by the COVID-19 pandemic. This allows the study to provide a clear snapshot of the state of Italian industries without the distortions introduced by the pandemic. While the primary focus is on data from 2019, the study also considers historical data where relevant to track the development of green industries over time and to place the findings within a broader temporal context. However, the emphasis remains on the most recent and comprehensive data available for the pre-pandemic period, ensuring that the analysis accurately reflects the state of the Italian economy at that time.

The data utilized in this study is drawn from multiple authoritative sources, ensuring its reliability and robustness. The primary dataset is the TEC-FRAMESBS, which provides detailed information on firms operating in Italy, including their export activities, industrial classifications, and geographic locations. This dataset is invaluable for identifying the export patterns of Italian provinces, a crucial aspect of understanding their specialization in green or vulnerable industries. Alternatives to TEC-FRAMESBS would be data from Eurostat, particularly the Environmental Goods and Services Sector (EGSS), which offers insights into industries directly involved in environmental protection and resource management. The EGSS data is instrumental in identifying sectors that can be classified as green based on their contributions to sustainability goals. Other significant sources include the International Energy Agency (IEA) for employment data related to the energy sector, which is critical for understanding the workforce implications of the green transition, and the U.S. Bureau of Labor Statistics (BLS) for methodological

references on classifying green jobs. Nevertheless, as anticipated, our choice is to exploit the classification developed in Alessi & Battiston (2022) which allows for a fine-grained understanding of the "green" and "brown" content of the industries under analysis.

Indeed, among the various frameworks available for identifying and categorizing green industries, the taxonomy developed by Alessi and Battiston (2022) stands out for its methodological rigor and its ability to address the complexities of the green transition. Unlike other approaches, such as the U.S. Bureau of Labor Statistics' Green Jobs classification or Eurostat's Environmental Goods and Services Sector (EGSS), which primarily focus on either the products or the industries themselves, the Alessi & Battiston taxonomy provides a dual-coefficient system that evaluates both the alignment of industries with sustainability goals and their vulnerability to structural changes. The Taxonomy Alignment Coefficient (TAC) and Taxonomy Exposure Coefficient (TEC) offer a more dynamic and context-sensitive analysis, capturing the multifaceted nature of industries that may simultaneously contribute to and be threatened by the transition to a low-carbon economy. This level of granularity makes the Alessi & Battiston framework particularly suited to our study, as it allows for a more precise identification of green industries and a deeper understanding of the regional disparities in Italy's economic landscape. By choosing this taxonomy, we are able to move beyond simpler categorizations and gain insights that are critical for developing effective and region-specific policy responses.

Descriptive statistics play a crucial role in providing a detailed overview of the spatial distribution of green and vulnerable industries across Italy's provinces. The use of maps, figures, and tables enhances the understanding of the data, offering an intuitive grasp of the key findings. Maps, for example, are employed to visualize the geographic distribution of green and vulnerable industries. A color gradient is used to indicate the level of specialization in green sectors across different provinces. Provinces with a high concentration of green industries are marked in darker shades, while those with lower concentrations are in lighter shades. This visual representation reveals clusters of green industry specialization, particularly in regions like Lombardy, Emilia-Romagna, and parts of Central and Southern Italy, where industrial activities align closely with environmental sustainability goals.

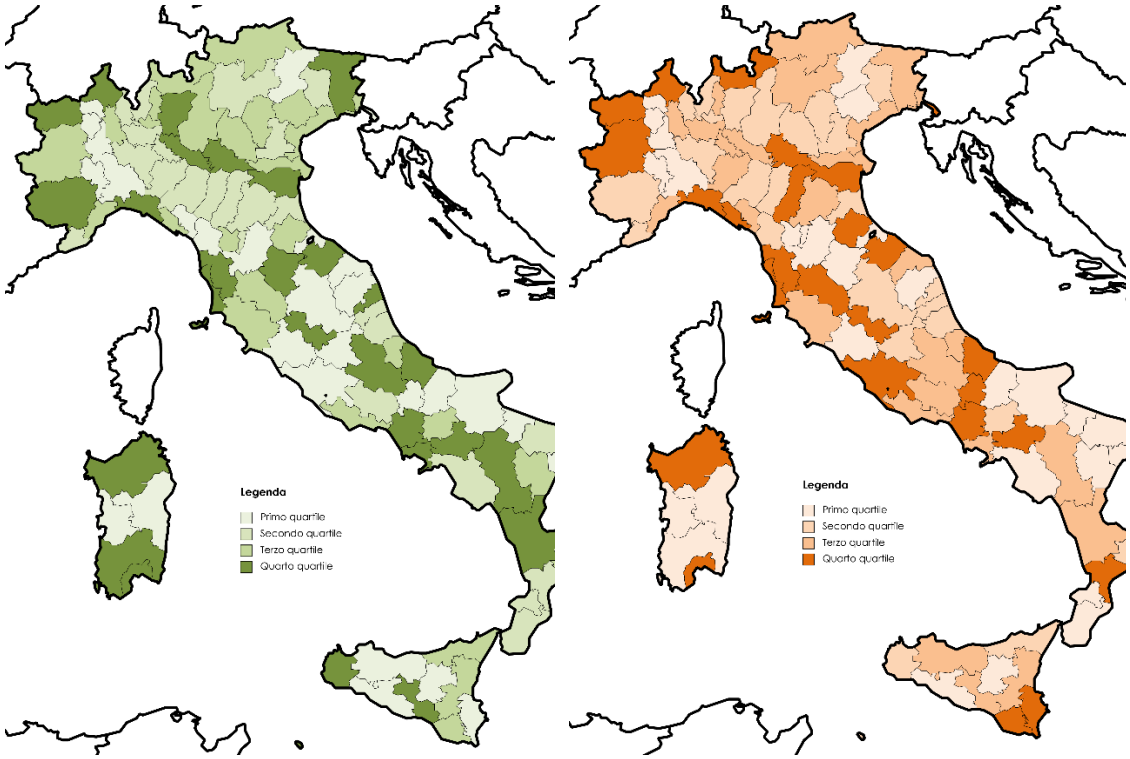
Similarly, another map highlights the distribution of vulnerable industries—those sectors at risk of decline due to the green transition. Again, a color gradient is used, with darker shades representing higher levels of specialization in vulnerable sectors. This map illustrates how certain provinces, such as Turin, Rome, and some coastal areas, are heavily dependent on industries like fossil fuels or other high-emission activities, which may face significant challenges in adapting to the green transition.

The two maps provided offer a visual representation of the distribution of green and vulnerable specializations across Italy's provinces, illustrating the varying degrees to which different regions are prepared for or at risk from the ongoing green transition. These maps are essential for understanding the regional disparities in how well different areas are aligned with the emerging

green economy and how exposed they are to the challenges posed by reliance on industries that may not align with future sustainability goals.

The first map, shaded in different tones of green, appears to represent the level of specialization in green industries (SPECG) across Italy's provinces. The map is divided into quartiles, with darker shades of green indicating provinces that rank higher in terms of their green specialization. This suggests that these areas have a stronger concentration of industries aligned with environmental sustainability and the green economy. Notably, Northern Italy shows a significant concentration of darker green areas, particularly in regions such as Lombardy, Veneto, and Emilia-Romagna. These regions, with their advanced industrial bases and investments in green technologies, renewable energy, and sustainable practices, are better positioned to thrive in a low-carbon future. Additionally, some central provinces, particularly in Tuscany and parts of Umbria, also show strong green specialization, likely due to their involvement in advanced manufacturing and renewable energy sectors. In contrast, many southern provinces are shaded in lighter green, indicating lower levels of green specialization. This highlights a lag in the transition to sustainable practices in these regions, which could present economic challenges as the global shift towards sustainability accelerates.

Figure N – Green specialization **Figure N – Vulnerable specialization**



Fonte: elaborazione degli autori su dati TEC-FRAMESBS e Alessi e Battiston (2022)

The second map, shaded in varying tones of orange, represents the level of specialization in vulnerable industries (SPECV). Darker shades indicate provinces with a higher concentration of industries that are at greater risk due to their reliance on fossil fuels, energy-intensive processes, or high emissions. The widespread distribution of darker orange areas across both Northern and Southern Italy indicates that vulnerability is not confined to any one part of the country. Even in regions with strong green specialization, such as parts of Lombardy and Piedmont, there are significant areas of vulnerability. This suggests that despite their progress in green industries, these regions still have substantial economic activities tied to traditional manufacturing sectors that have yet to fully transition to sustainable practices. In Southern Italy, the darker orange shading in many provinces indicates a higher degree of vulnerability, consistent with the observation that these regions have less diversified economies and are more dependent on industries that could face significant challenges in the transition to a green economy.

The juxtaposition of these two maps reveals the dual challenges that Italy faces in navigating the green transition. Northern regions, while leading in green specialization, also show significant pockets of vulnerability, indicating that even the most advanced areas must carefully balance the growth of green industries with the management of risks associated with their traditional economic activities. Southern Italy, on the other hand, faces a more complex and daunting challenge, with lower levels of green specialization and higher vulnerability, putting these regions at greater risk of economic decline if they do not accelerate their transition towards more sustainable practices. These maps underscore the urgent need for targeted interventions that support regions in their green transition, ensuring that no area is left behind. The clear visual disparity between green specialization and vulnerability highlights the importance of tailored regional policies that consider the unique industrial compositions of each province. Successfully managing this dual challenge of fostering green growth while mitigating economic vulnerability will be crucial for Italy's overall success in adapting to the green economy.

Figures are used to depict trends and correlations within the data, providing a graphical representation of critical insights. For instance, a scatter plot correlates the specialization in green industries with the level of vulnerability in each province. This figure is particularly useful for identifying provinces that occupy precarious positions—those that are leaders in green industries but also heavily reliant on vulnerable sectors. Conversely, it also helps to highlight provinces that are well-positioned for the green transition, with high levels of green specialization and low vulnerability, as well as those at risk of economic decline due to low green specialization and high vulnerability. Another significant figure presents time series data, showing the growth of green industries over the past decade. This figure highlights how some provinces have successfully transitioned towards more sustainable industries, while others have lagged behind, offering a temporal context for understanding the evolution of different regions' industrial compositions leading up to 2019.

Tables complement these visual aids by providing a more detailed breakdown of the data, offering specific figures for each province. For example, one table lists the top 10 provinces in terms of

green industry specialization, along with their corresponding levels of vulnerability. This allows for easy comparison between provinces and provides a clear ranking that can guide policy interventions. Another table presents the export values for green and vulnerable industries by province, detailing how much each province contributes to Italy's overall green exports and how much of its economy is at risk due to vulnerable sectors. These tables are crucial for understanding the economic impact of the green transition on different regions and for identifying which areas might require targeted support to mitigate potential disruptions.

Overall, the data and descriptive statistics presented in this study provide a comprehensive overview of the current state of green and vulnerable industries across Italy's provinces. By combining detailed territorial references, time coverage, and authoritative data sources with clear visual and statistical representations, this section offers a thorough understanding of the spatial distribution and economic significance of these industries. This robust foundation is essential for informing the development of targeted industrial policies that support the green transition while addressing the specific needs of Italy's diverse regions.

4. Methodology

The methodology employed in this study is designed to provide a rigorous and comprehensive analysis of the green and vulnerable industries across Italy's provinces. The approach integrates both quantitative and qualitative methods to ensure that the findings are robust, reliable, and relevant for informing policy decisions. This section explains the specific methods used and provides a justification for their selection, ensuring that the research objectives are met effectively.

The primary methodological approach in this study is quantitative, leveraging advanced statistical techniques to analyze large datasets and derive meaningful insights. The choice of a quantitative approach is driven by the need to objectively measure the extent of green and vulnerable industry specialization across different provinces. By using quantitative methods, the study can systematically compare provinces, identify patterns, and establish correlations between different variables, such as the degree of green industry specialization and the level of economic vulnerability to the green transition.

Central to the methodology is the use of the TEC-FRAMESBS dataset, which provides detailed information on firms' export activities, industrial classifications, and geographic locations. This dataset is instrumental in calculating the indices of green and vulnerable industry specialization at the provincial level. The use of export data is particularly justified because exports are a strong indicator of a region's industrial strengths and its integration into global markets. Firms that are competitive enough to export typically reflect the broader industrial capabilities of their region, making export data a valuable proxy for understanding regional industrial specializations.

To quantify the degree of specialization in green and vulnerable industries, the study employs two key indices: the Taxonomy Alignment Coefficient (TAC) and the Taxonomy Exposure Coefficient (TEC). These indices, developed by Alessi and Battiston (2022), are used to assess the alignment of industries with sustainability goals (TAC) and their vulnerability to the green transition (TEC). The TAC measures the extent to which a sector's activities are aligned with the objectives of a low-carbon economy, such as through the production of renewable energy or the adoption of energy-efficient technologies. Conversely, the TEC measures the degree to which a sector is dependent on fossil fuels or other high-emission activities, making it vulnerable to future regulatory changes and market shifts aimed at reducing carbon emissions. These indices are calculated at the four-digit NACE classification level, which provides a high degree of granularity and allows for a detailed assessment of industry specializations. The four-digit NACE classification is chosen because it offers a precise categorization of economic activities, enabling the study to capture nuanced differences between sectors. This level of detail is crucial for accurately identifying which industries are green, which are vulnerable, and how these industries are distributed across Italy's provinces.

The calculation of the TAC and TEC indices involves several steps. First, the proportion of each industry's activities that can be classified as green or vulnerable is determined using sector-specific data on emissions, energy consumption, and other relevant environmental indicators. These proportions are then used to assign TAC and TEC scores to each industry within a province. The scores are weighted by the economic significance of each industry within the province, as measured by its contribution to provincial exports. This weighted approach ensures that the indices reflect not just the presence of green or vulnerable industries, but also their relative importance to the provincial economy. Below, we report an example for the Province of Roma that illustrates this step of the methodology.

Table 2 – Green/Vulnerable Export Basket – Province of Rome

ATECO	Sector Name	TAC	TEC	Export Percentage
0610	Crude Petroleum Extraction	0	1	0.10%
7711	Renting of Cars and Light Motor Vehicles	0.003	0.997	0.32%
6820	Renting and Operating of Own or Leased Real Estate	0.15	0.7	0.11%
5110	Passenger Air Transport	0	1	0.17%
5020	Sea and Coastal Freight Water Transport	0	1	0.15%

Table 2 – Green/Vulnerable Export Basket – Province of Rome

ATECO	Sector Name	TAC	TEC	Export Percentage
4671	Wholesale of Solid, Liquid, Gaseous Fuels and Related Products	0	1	9.51%
4511	Sale of Cars and Light Motor Vehicles	0	0.98	1.80%
4120	Construction of Residential and Non-residential Buildings	0.4	0	0.10%
3030	Manufacture of Aircraft, Spacecraft, and Related Devices	0	1	22.90%
1920	Manufacture of Refined Petroleum Products	0	1	3.63%
	Green specialization	0.00000459	Vulnerable specialization	0.00101

Source: Authors' calculations based on TEC-FRAMESBS data and Alessi & Battiston (2022).
Note: The table includes only the top 10 sectors where TEC or TAC are non-zero.

This table provides a detailed snapshot of the export composition for the Province of Rome, focusing on sectors classified by their green (SPECG) and vulnerable (SPECV) specializations. The analysis employs the Taxonomy Alignment Coefficient (TAC) and Taxonomy Exposure Coefficient (TEC) to quantify the extent to which these sectors align with or are vulnerable to the green transition.

From the table, we observe that the manufacturing of aircraft, spacecraft, and related devices (ATECO 3030) dominates Rome's export profile, constituting 22.9% of total exports. This sector is entirely classified as vulnerable (TEC = 1) with no alignment to green objectives (TAC = 0), highlighting its significant exposure to the risks posed by the transition to a low-carbon economy. Similarly, the wholesale of fuels (ATECO 4671) and the manufacture of refined petroleum products (ATECO 1920) contribute 9.51% and 3.63% to exports, respectively, and are also fully vulnerable (TEC = 1) without any green specialization (TAC = 0). These industries are heavily reliant on fossil fuels, making them susceptible to declines as sustainability becomes increasingly prioritized.

Other notable sectors include the crude petroleum extraction (ATECO 0610) and the passenger air transport (ATECO 5110), both of which also show complete vulnerability with no green alignment. Even though these sectors represent smaller percentages of the total exports, their

total TEC scores reinforce the idea that Rome's economy has substantial exposure to vulnerable sectors.

On the other hand, sectors with some degree of green specialization, such as the construction of residential and non-residential buildings (ATECO 4120) and renting and operating of real estate (ATECO 6820), show relatively low TAC scores (0.4 and 0.15 respectively) and contribute minimally to the overall exports. These green-aligned sectors do not compensate for the high level of vulnerability found in the province's major export activities.

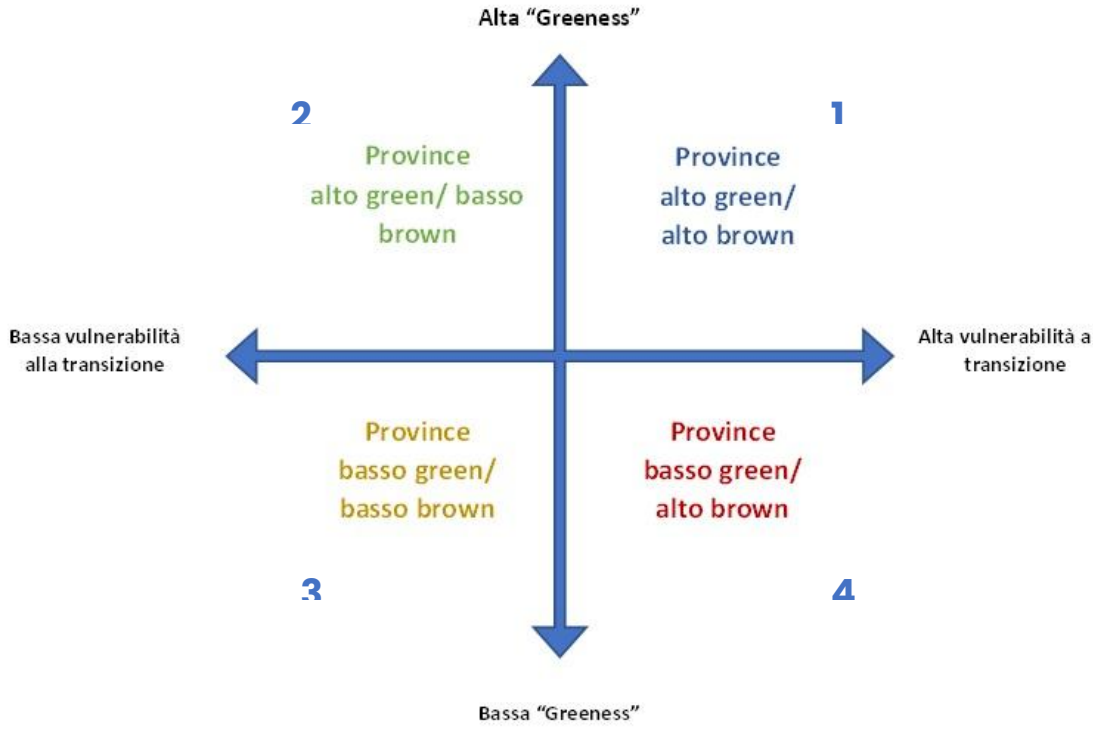
The overall SPECG score for Rome is extremely low (0.00000459), indicating that green industries constitute a negligible portion of the province's economic output. Conversely, the SPECV score is higher (0.00101), reflecting the significant presence of vulnerable sectors. This imbalance suggests that Rome's industrial structure is currently ill-prepared for the demands of the green transition, with a heavy reliance on sectors that may face economic decline as global policies and markets shift towards sustainability.

The results for Rome highlight the critical need for strategic economic diversification and the enhancement of green industries to mitigate potential risks associated with the province's current economic reliance on vulnerable sectors. This example illustrates how the methodology can be applied to provide a detailed provincial outlook, offering insights into both the strengths and vulnerabilities of different regions in the context of the green transition.

In addition to the quantitative analysis, the study also incorporates qualitative methods to contextualize the findings and provide deeper insights into the implications of the green transition for different regions. This qualitative component includes a review of policy documents, expert interviews, and case studies of specific provinces that exemplify the broader trends identified in the quantitative analysis. The qualitative analysis is justified because it allows the study to explore the underlying factors driving regional differences in green industry specialization and vulnerability. It also provides a more nuanced understanding of the challenges and opportunities that different provinces face in the green transition, which cannot be fully captured by quantitative data alone.

The selection of provinces for case studies is based on their positioning in the TAC-TEC matrix (see Figure below). Provinces that exhibit high levels of both green specialization and vulnerability, as well as those that are strong in green industries but low in vulnerability, are chosen for in-depth analysis. This ensures that the case studies reflect a range of experiences and provide insights into both the challenges and best practices associated with the green transition.

Figure N - TAC-TEC matrix



Source: own authors' elaboration

The methodology is also informed by the need to ensure the relevance and applicability of the findings to policy-making. By combining quantitative measures with qualitative insights, the study aims to provide a comprehensive understanding of the green transition that is grounded in empirical data but also sensitive to the specific contexts and needs of different regions. This approach is particularly important for informing industrial policy, as it allows for the identification of targeted interventions that can support regions in transitioning to a green economy while mitigating the risks associated with economic vulnerability.

In summary, the methodology used in this study is designed to provide a robust and comprehensive analysis of green and vulnerable industries across Italy's provinces. The use of advanced quantitative techniques, combined with qualitative contextual analysis, ensures that the findings are both empirically rigorous and relevant for policy-making. The selection of TAC and TEC indices, the focus on provincial-level data, and the integration of qualitative insights are all justified by the study's objectives of identifying regional strengths and vulnerabilities in the green transition and providing actionable recommendations for industrial policy.

5. Findings – Discussion

The analysis of green and vulnerable industries across Italy's provinces reveals a complex and uneven landscape that reflects the diverse economic structures and industrial capabilities of the country. By applying the Taxonomy Alignment Coefficient (TAC) and Taxonomy Exposure Coefficient (TEC), this study uncovers significant variations in how different regions are positioned within the green transition, with some provinces showing strong potential for growth in sustainable industries while others are more heavily dependent on sectors that may face decline.

A prominent finding is the marked geographic concentration of green industries in Northern Italy, particularly in provinces such as Lombardy, Emilia-Romagna, and Veneto. These regions exhibit high TAC scores, indicating a strong alignment with green economy objectives. The economic structure of these provinces is characterized by a significant presence of industries involved in renewable energy production, energy-efficient manufacturing, and other sectors that are pivotal to achieving a low-carbon economy. The high levels of specialization in green industries suggest that these provinces are not only prepared to adapt to the ongoing green transition but are also likely to be key drivers of economic growth in this emerging sector.

In contrast, several provinces, especially in Southern Italy and certain coastal areas, display high levels of vulnerability as indicated by their TEC scores. Provinces such as Rome, Naples, and others in the South are characterized by economies that rely heavily on traditional industries with significant carbon footprints, such as fossil fuel extraction, conventional manufacturing, and energy-intensive sectors. These provinces face a challenging economic landscape as the global shift towards sustainability may result in decreased demand for their primary industrial outputs. The high TEC scores in these regions reflect the potential economic risks associated with a delayed or unmanaged transition to greener industries, as these areas could experience declines in industrial output and employment if current trends continue.

The scatter plot provides a detailed visual representation of the relationship between green specialization (SPECG) and vulnerable specialization (SPECV) across various Italian provinces, each represented by a two-letter code. The x-axis measures vulnerable specialization, with higher values indicating a greater reliance on industries that may be at risk due to the green transition. The y-axis, on the other hand, measures green specialization, with higher values reflecting a stronger alignment with sustainable, low-carbon economy industries.

Figure N – Italian provinces scattered over the TEC-TAC matrix

What immediately stands out is the general clustering of provinces near the origin, indicating that many regions have low levels of both green and vulnerable specialization. This suggests that these provinces have a limited involvement in either green or high-risk industries, potentially reflecting a diversified economy or one with less defined industrial specializations. For instance, economically significant provinces such as Milan (MI), Bologna (BO), and Turin (TO) are located in this cluster. Despite their economic weight, these regions show relatively low specialization in both categories, which might indicate a balance in their industrial activities, avoiding heavy dependence on sectors that are either strongly green or particularly vulnerable.

One of the most striking observations is the outlier position of Aosta (AO), which exhibits the highest level of green specialization while maintaining very low vulnerable specialization. This unique positioning suggests that Aosta has a strong focus on sustainable industries with minimal reliance on sectors that are at risk in the green transition. Such a profile positions Aosta as a potential leader in Italy's move towards a green economy. Similarly, provinces like Terni (TR) and Cagliari (CA) also demonstrate relatively higher levels of green specialization, though they still maintain moderate levels of vulnerable specialization. This indicates that while these provinces are engaged in green industries, they have not completely mitigated their reliance on more vulnerable sectors.

On the other end of the spectrum, Catanzaro (CZ) emerges as a notable outlier with high vulnerable specialization and almost no green specialization. This positioning suggests that Catanzaro's economy is heavily dependent on industries that are likely to face significant challenges in the green transition, without the mitigating influence of green industries. Such a

profile could make the province particularly susceptible to economic disruption as sustainability becomes an increasingly dominant factor in global markets.

The distribution along the x-axis indicates that most provinces have low to moderate levels of vulnerable specialization, with only a few exhibiting high levels. This suggests that while many regions in Italy do not rely heavily on industries at risk, those that do are concentrated in specific areas, which could lead to regional economic challenges if these vulnerabilities are not addressed. Conversely, the y-axis distribution reveals that green specialization is generally low across most provinces, with only a few exceptions, like Aosta, showing significant engagement in green sectors (nevertheless, its low dimension, makes the emergence of the phenomenon much easier than larger regional economies). This underlines the need for a broader adoption of green industries across more regions to ensure economic resilience in the face of the green transition.

In summary, the scatter plot highlights the diverse economic landscapes across Italy's provinces, with some regions like Aosta being well-positioned for the green transition, while others like Catanzaro face significant challenges due to their reliance on vulnerable industries. The visualization underscores the importance of targeted strategies that take into account the specific industrial compositions of each province, whether that involves bolstering green industries or mitigating the risks associated with vulnerable sectors.

The study also identifies provinces that exhibit a dual specialization, meaning they have significant activity in both green and vulnerable industries. Turin is a prime example of this duality. On one hand, Turin is a major hub for automotive manufacturing, including the production of electric vehicles and green automotive technologies, which is reflected in its high TAC scores. On the other hand, the city still has a substantial reliance on traditional automotive manufacturing and related industries that are less aligned with green economy goals, leading to elevated TEC scores as well. This dual specialization creates a unique economic scenario where the region is simultaneously positioned to benefit from the green transition and at risk of economic challenges if traditional sectors fail to adapt.

The findings also highlight the persistent economic disparities between Northern and Southern Italy, which are exacerbated by the green transition. The Northern regions, with their well-established industrial bases, advanced infrastructure, and higher levels of innovation, are better equipped to integrate green technologies and capitalize on new economic opportunities. In contrast, Southern regions, with less developed industrial bases and infrastructure, are more susceptible to the risks posed by the transition away from carbon-intensive industries. This North-South divide in Italy's economic landscape is a critical factor in understanding the uneven distribution of green and vulnerable industries across the country.

Another important insight from the study is the relationship between export orientation and industrial specialization in green and vulnerable sectors. Provinces with a strong export orientation, particularly those in the North, tend to have higher TAC scores, reflecting their competitive advantage in green industries on a global scale. This export-driven green specialization suggests that these provinces are not only important players in the domestic

economy but also crucial contributors to Italy's position in the global green economy. Conversely, provinces with lower export orientation and higher TEC scores are more likely to be inward-looking economies that may struggle to maintain competitiveness as international markets increasingly favor sustainable products and practices.

Table N - Specialization of the Top 10 and Bottom 10 Provinces by Export Value

Province	Export Value (in millions)	Green Specialization	Vulnerable Specialization
Top 10			
Milan	€71,720	Low	Low
Turin	€30,248	Low	High
Rome	€20,400	Low	High
Vicenza	€18,183	Low	Low
Bergamo	€15,443	High	Low
Florence	€15,199	Low	Low
Brescia	€15,122	High	Low
Bologna	€13,841	Low	High
Modena	€13,632	Low	High
Treviso	€12,756	Low	Low
Bottom 10			
Potenza	€ 74.23	High	High
Catanzaro	€ 60.96	Low	High
Cosenza	€ 54.18	High	High
Caltanissetta	€ 52.84	High	Low
Isernia	€ 33.07	Low	High
Oristano	€ 32.12	Low	Low
Nuoro	€ 21.52	Low	Low
Vibo Valentia	€ 20.16	Low	Low
Crotone	€ 14.78	Low	Low
Enna	€ 10.97	Low	Low

The table presents a clear comparison between the top 10 and bottom 10 Italian provinces based on their export values, alongside their respective levels of green specialization and vulnerable specialization. This offers insight into how different regions are positioned in relation to the green transition, particularly concerning their industrial focus and export activities.

Among the top 10 exporting provinces, Milan leads significantly with €71.7 billion in exports, yet it is characterized by both low green and vulnerable specialization. This suggests a balanced, diversified industrial base with neither a strong focus on green industries nor significant exposure

to industries that may face challenges in the green transition. Milan's economic stability and diversification may provide it with resilience in adapting to future industrial shifts.

Turin and Rome are notable for their combination of high export values with low green specialization and high vulnerable specialization. This indicates a heavy reliance on industries that are at risk in the context of the green transition, such as traditional automotive and fossil fuel-related industries. These provinces may face economic challenges if they do not diversify and invest more in green sectors.

In contrast, Bergamo and Brescia stand out for their high green specialization and low vulnerable specialization, coupled with substantial export values. These provinces are well-positioned to benefit from the green transition, with a strong presence in industries that align with sustainability goals. Their ability to maintain low exposure to vulnerable industries while also achieving high export levels suggests a forward-looking industrial strategy that could serve as a model for other regions.

Vicenza, Florence, and Treviso also show low levels of both green and vulnerable specialization, similar to Milan. These provinces may have diversified industrial bases that are not heavily dependent on either green or at-risk industries, which could make their economies more adaptable to changes brought about by the green transition.

Among the bottom 10 exporting provinces, Potenza, Cosenza, and Caltanissetta are particularly interesting. Despite their relatively low export values, these provinces show high green specialization, indicating a potential focus on sustainable industries. However, both Potenza and Cosenza also have high vulnerable specialization, suggesting that their economies are still partly reliant on at-risk industries. This duality could make their green transition more complex, as they balance the growth of green sectors with the decline of vulnerable ones.

In contrast, provinces like Catanzaro, Isernia, and Oristano are characterized by low green specialization and high vulnerable specialization, coupled with very low export values. These provinces may be at significant risk in the green transition, with economies that are both small and heavily dependent on industries that could decline. Without strategic interventions to diversify their industrial bases and invest in green sectors, these regions could face economic hardship.

Finally, Nuoro, Vibo Valentia, Crotone, and Enna show both low green and low vulnerable specialization, indicating minimal engagement in either category. With their low export values, these provinces may have limited industrial activity overall, making it crucial to consider how they can be integrated into broader economic strategies that promote sustainable development.

Overall, the table highlights the diverse economic landscapes across Italy's provinces, emphasizing the varying degrees of readiness for the green transition. While some provinces are clearly positioned to lead in the green economy, others face significant challenges due to their reliance on vulnerable industries. This comparison underscores the importance of tailored strategies that address the specific needs and opportunities of each region, ensuring that all provinces can navigate the green transition successfully.

Merging the findings of the study with historical considerations of Italian economic development brings to compelling territorial considerations. Northern provinces, which already had a solid industrial foundation, have more possibilities to accelerate growth in green industries, driven by investments in technology and infrastructure that support sustainability. This trend suggests a positive trajectory towards further economic resilience and growth in these regions. Meanwhile, the allocation of vulnerable industries is likely to be more static in their evolution, particularly in the South, where there has been less movement towards adopting green technologies and practices. This stagnation suggests that without significant shifts in industrial focus, these regions may face increasing economic difficulties as the green transition progresses.

Economically, the findings suggest that Italy's green transition is likely to be characterized by a divergence in regional economic outcomes. The provinces that are already aligned with green economic activities are expected to see continued economic growth and diversification, leveraging their existing industrial strengths to adapt to and lead in the green economy. In contrast, regions that are heavily invested in traditional, vulnerable industries may experience economic contraction or stagnation unless they can transition towards more sustainable industries. The concentration of green industries in the North and the vulnerability of the South highlights the need for a nuanced understanding of regional economic dynamics in the context of the green transition.

In summary, the findings of this study illustrate the uneven distribution of green and vulnerable industries across Italy's provinces, with significant implications for regional economic trajectories. The green transition is likely to reinforce existing economic strengths in some regions while posing serious challenges to others, particularly those reliant on industries that are less adaptable to the demands of a low-carbon economy. These insights provide a crucial foundation for understanding the economic implications of the green transition across Italy and underscore the importance of ongoing analysis as the transition continues to unfold.

1.6. Policy implications and recommendations

he findings of this study underscore the critical importance of targeted and region-specific policy interventions to manage the green transition effectively across Italy's diverse economic landscape. As the green transition accelerates, it presents both opportunities and challenges that are unevenly distributed across the country. The policy implications drawn from this study highlight the need for differentiated strategies that address the unique circumstances of each region while fostering overall national economic resilience and sustainability.

One of the most significant policy implications is the necessity for a dual approach that both supports the expansion of green industries in already strong regions and mitigates the risks faced by provinces heavily reliant on vulnerable sectors. In Northern Italy, where provinces like Lombardy, Emilia-Romagna, and Veneto show high specialization in green industries, policies should focus on further enhancing these regions' competitive advantages. This could include increased investment in research and development (R&D) for green technologies, subsidies for green innovation, and incentives for businesses to expand their sustainable operations.

Additionally, facilitating access to international markets for green products through trade agreements and export support would strengthen these regions' positions in the global green economy.

Conversely, in Southern Italy and other regions with high levels of vulnerability, policies must prioritize economic diversification and the transition away from industries that are likely to decline due to the global shift towards sustainability. This could involve the gradual phasing out of subsidies and support for high-emission industries, coupled with targeted investments in new, sustainable industries that can replace the economic activity currently dominated by vulnerable sectors. For example, developing renewable energy projects, such as solar and wind power, in the sunny and windy southern regions could create new economic opportunities and reduce dependency on fossil fuels.

For provinces that exhibit dual specialization in both green and vulnerable industries, such as Turin, a balanced policy approach is necessary. Here, the goal should be to manage the decline of vulnerable sectors in a way that minimizes economic disruption while simultaneously fostering the growth of green industries. This could be achieved through policies that support the retraining and upskilling of workers, enabling them to transition from declining industries to emerging green sectors. Moreover, targeted support for small and medium-sized enterprises (SMEs) in these regions could help them innovate and adapt to the changing economic environment.

The study also highlights the importance of addressing regional disparities through national-level coordination. While local and regional policies are crucial for addressing specific needs, a coherent national strategy is essential to ensure that all regions benefit from the green transition. This might involve redistributing resources and investments from wealthier, green-specialized regions to those lagging behind, thereby reducing the economic divide between the North and South. The development of national infrastructure projects, such as smart grids and efficient transportation networks, could also support the green transition across all regions, enhancing connectivity and enabling regions with lower green specialization to integrate into the broader green economy.

Furthermore, the findings suggest that policies should be adaptive and responsive to the dynamic nature of the green transition. As new technologies emerge and global market conditions evolve, policy frameworks must be flexible enough to accommodate these changes. This requires continuous monitoring of economic indicators related to green and vulnerable industries, as well as regular reviews and updates to policy strategies. By doing so, policymakers can ensure that interventions remain relevant and effective, enabling Italy to maintain its competitive edge in the green economy.

Another key recommendation is the need for stronger collaboration between public and private sectors. The green transition is a multifaceted challenge that requires the combined efforts of government, industry, and civil society. Public-private partnerships can play a vital role in driving

innovation, scaling up green technologies, and ensuring that the benefits of the green transition are widely shared. For instance, governments can work with private companies to develop green industrial zones or innovation clusters that concentrate resources and expertise in specific areas, thereby accelerating the growth of green industries.

In addition, there is a need for comprehensive education and training programs that equip the workforce with the skills necessary for the green economy. As traditional industries decline, the demand for new skills in areas such as renewable energy, energy efficiency, and sustainable manufacturing will increase. Governments should invest in education systems and vocational training programs that align with the needs of the green economy, ensuring that workers are prepared to take advantage of new job opportunities. This will also help mitigate the social impacts of the green transition, particularly in regions where job losses in vulnerable industries could otherwise lead to economic hardship.

Finally, the study highlights the importance of fostering a culture of innovation and entrepreneurship in all regions, particularly in those currently lagging in green specialization. Encouraging the development of start-ups and new ventures in green technologies can stimulate economic growth and create new job opportunities. Policies that provide financial support, mentorship, and networking opportunities for entrepreneurs can help nurture a new generation of businesses that contribute to the green economy.

In conclusion, the policy implications and recommendations arising from this study emphasize the need for a strategic, multi-faceted approach to managing the green transition in Italy. By addressing the specific needs of different regions, fostering innovation, and ensuring that the benefits of the green economy are widely shared, Italy can navigate the challenges of the green transition and emerge as a leader in the global shift towards sustainability. The recommendations provided here offer a roadmap for policymakers as they seek to harness the opportunities of the green transition while mitigating its risks, ensuring a prosperous and sustainable future for all regions of the country.

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Technical Appendices

Table A1. List of Provinces by TEC-TAC matrix quadrant of belonging

Code	Name	Green	Brown	Code	Name	Green	Brown
BO	Bologna	Basso	Alto	BI	Biella	Basso	Basso
BR	Brindisi	Basso	Alto	BL	Belluno	Basso	Basso
CZ	Catanzaro	Basso	Alto	BN	Benevento	Basso	Basso
FC	Forlì-Cesena	Basso	Alto	BT	Barletta-Andria-Trani	Basso	Basso
IS	Isernia	Basso	Alto	BZ	Bolzano	Basso	Basso
MO	Modena	Basso	Alto	CB	Campobasso	Basso	Basso
PE	Pescara	Basso	Alto	CO	Como	Basso	Basso
RM	Roma	Basso	Alto	CT	Catania	Basso	Basso
RO	Rovigo	Basso	Alto	EN	Enna	Basso	Basso
SI	Siena	Basso	Alto	FG	Foggia	Basso	Basso
SO	Sondrio	Basso	Alto	FI	Firenze	Basso	Basso
SP	LaSpezia	Basso	Alto	FR	Frosinone	Basso	Basso
SR	Siracusa	Basso	Alto	GO	Gorizia	Basso	Basso
TO	Torino	Basso	Alto	IM	Imperia	Basso	Basso
TS	Trieste	Basso	Alto	KR	Crotone	Basso	Basso
AO	Valled'Aosta	Alto	Alto	LC	Lecco	Basso	Basso
AV	Avellino	Alto	Alto	LE	Lecce	Basso	Basso
CA	Cagliari	Alto	Alto	LO	Lodi	Basso	Basso
CE	Caserta	Alto	Alto	LT	Latina	Basso	Basso
CH	Chieti	Alto	Alto	LU	Lucca	Basso	Basso
CR	Cremona	Alto	Alto	MB	MonzaeBrianza	Basso	Basso
CS	Cosenza	Alto	Alto	MC	Macerata	Basso	Basso
FE	Ferrara	Alto	Alto	ME	Messina	Basso	Basso
GE	Genova	Alto	Alto	MI	Milano	Basso	Basso
LI	Livorno	Alto	Alto	MS	Massa-Carrara	Basso	Basso
MN	Mantova	Alto	Alto	NO	Novara	Basso	Basso
PI	Pisa	Alto	Alto	NU	Nuoro	Basso	Basso
PU	PesaroeUrbino	Alto	Alto	OR	Oristano	Basso	Basso
PZ	Potenza	Alto	Alto	PA	Palermo	Basso	Basso
RG	Ragusa	Alto	Alto	PC	Piacenza	Basso	Basso
SS	Sassari	Alto	Alto	PD	Padova	Basso	Basso
TR	Terni	Alto	Alto	PG	Perugia	Basso	Basso
UD	Udine	Alto	Alto	PN	Pordenone	Basso	Basso
VB	VerbanoCusioOssola	Alto	Alto	PO	Prato	Basso	Basso
AQ	L'Aquila	Alto	Basso	PR	Parma	Basso	Basso

AR	Arezzo	Alto	Basso
BG	Bergamo	Alto	Basso
BS	Brescia	Alto	Basso
CL	Caltanissetta	Alto	Basso
CN	Cuneo	Alto	Basso
FM	Fermo	Alto	Basso
GR	Grosseto	Alto	Basso
MT	Matera	Alto	Basso
NA	Napoli	Alto	Basso
SU	SudSardegna	Alto	Basso
SV	Savona	Alto	Basso
TP	Trapani	Alto	Basso
VE	Venezia	Alto	Basso
AG	Agrigento	Basso	Basso
AL	Alessandria	Basso	Basso
AN	Ancona	Basso	Basso
AP	AscoliPiceno	Basso	Basso
AT	Asti	Basso	Basso
BA	Bari	Basso	Basso
PT	Pistoia	Basso	Basso
PV	Pavia	Basso	Basso
RA	Ravenna	Basso	Basso
RC	ReggioCalabria	Basso	Basso
RE	ReggioEmilia	Basso	Basso
RI	Rieti	Basso	Basso
RN	Rimini	Basso	Basso
SA	Salerno	Basso	Basso
TA	Taranto	Basso	Basso
TE	Teramo	Basso	Basso
TN	Trento	Basso	Basso
TV	Treviso	Basso	Basso
VA	Varese	Basso	Basso
VC	Vercelli	Basso	Basso
VI	Vicenza	Basso	Basso
VR	Verona	Basso	Basso
VT	Viterbo	Basso	Basso
VV	ViboValentia	Basso	Basso

Table A2. List of Values by Province

Code	Name	Green specializ.	Vulnerable specializ.	Code	Name	Green specializ.	Vulnerable specializ.
AG	Agrigento	0.01	0.02	MO	Modena	0.02	0.91
AL	Alessandria	0.01	0.07	MS	Massa-Carrara	0.01	0.44
AN	Ancona	0.01	0.34	MT	Matera	0.05	0.01
AO	Valled'Aosta-Aosta/Aoste	0.31	3.78	NA	Napoli	0.19	0.40
AP	AscoliPiceno	0.02	0.17	NO	Novara	0.04	0.34
AQ	L'Aquila	0.07	0.47	NU	Nuoro	0.00	0.03
AR	Arezzo	0.06	0.02	OR	Oristano	0.01	0.04
AT	Asti	0.00	0.03	PA	Palermo	0.00	0.50
AV	Avellino	0.17	1.29	PC	Piacenza	0.01	0.34
BA	Bari	0.02	0.07	PD	Padova	0.02	0.10
BG	Bergamo	0.08	0.25	PE	Pescara	0.04	0.58
BI	Biella	0.00	0.00	PG	Perugia	0.01	0.13
BL	Belluno	0.00	0.02	PI	Pisa	0.10	1.63
BN	Benevento	0.04	0.11	PN	Pordenone	0.02	0.15
BO	Bologna	0.01	0.56	PO	Prato	0.03	0.01
BR	Brindisi	0.03	0.92	PR	Parma	0.01	0.12
BS	Brescia	0.05	0.27	PT	Pistoia	0.05	0.06
BT	Barletta-Andria-Trani	0.01	0.03	PU	PesaroeUrbino	0.06	0.79
BZ	Bolzano	0.05	0.33	PV	Pavia	0.02	0.13
CA	Cagliari	0.26	2.63	PZ	Potenza	0.12	0.59
CB	Campobasso	0.00	0.06	RA	Ravenna	0.02	0.20
CE	Caserta	0.09	0.89	RC	ReggioCalabria	0.01	0.07
CH	Chieti	0.06	2.56	RE	ReggioEmilia	0.02	0.17
CL	Caltanissetta	1.19	0.37	RG	Ragusa	0.06	1.68
CN	Cuneo	0.08	0.10	RI	Rieti	0.00	0.12
CO	Como	0.01	0.14	RM	Roma	0.00	1.01
CR	Cremona	0.08	0.63	RN	Rimini	0.01	0.04
CS	Cosenza	0.12	0.58	RO	Rovigo	0.05	0.51
CT	Catania	0.05	0.43	SA	Salerno	0.01	0.07
CZ	Catanzaro	0.03	2.48	SI	Siena	0.03	1.01
EN	Enna	0.00	0.02	SO	Sondrio	0.04	0.88
FC	Forlì-Cesena	0.04	0.88	SP	LaSpezia	0.03	4.48
FE	Ferrara	0.20	1.22	SR	Siracusa	0.00	10.70
FG	Foggia	0.01	0.03	SS	Sassari	0.13	1.18
FI	Firenze	0.00	0.04	SU	SudSardegna	0.51	0.02
FM	Fermo	0.09	0.08	SV	Savona	0.06	0.31
FR	Frosinone	0.03	0.34	TA	Taranto	0.01	0.06
GE	Genova	0.07	1.08	TE	Teramo	0.03	0.20
GO	Gorizia	0.04	0.38	TN	Trento	0.02	0.33
GR	Grosseto	0.05	0.29	TO	Torino	0.03	1.30
IM	Imperia	0.02	0.18	TP	Trapani	0.16	0.09
IS	Isernia	0.00	0.73	TR	Terni	0.28	2.79
KR	Crotone	0.04	0.14	TS	Trieste	0.00	4.41
LC	Lecco	0.05	0.32	TV	Treviso	0.03	0.04

LE	Lecce	0.02	0.09	UD	Udine	0.07	0.63
LI	Livorno	0.15	1.84	VA	Varese	0.01	0.19
LO	Lodi	0.02	0.36	VB	Verbano-Cusio-Ossola	0.14	1.31
LT	Latina	0.03	0.28	VC	Vercelli	0.01	0.03
LU	Lucca	0.00	0.19	VE	Venezia	0.05	0.35
MB	MonzaeBrianza	0.03	0.10	VI	Vicenza	0.04	0.13
MC	Macerata	0.01	0.04	VR	Verona	0.05	0.10
ME	Messina	0.03	0.12	VT	Viterbo	0.01	0.01
MI	Milano	0.02	0.29	VV	ViboValentia	0.01	0.02
MN	Mantova	0.10	0.90		**National average**	**0.06**	**0.67**

Source: Authors' calculations based on TEC-FRAMESBS data and Alessi and Battiston (2022).

Source: Authors' calculations based on TEC-FRAMESBS data and Alessi and Battiston (2022). Note: To make the index values more readable despite their small magnitude, they have been multiplied by 1000.

Table A3. List of Values by Region

Region	Green specializ.	Vulnerable specializ.
Abruzzo	0.05	0.95
Basilicata	0.09	0.30
Calabria	0.04	0.66
Campania	0.10	0.55
Emilia-Romagna	0.04	0.49
Friuli-Venezia Giulia	0.03	1.39
Lazio	0.01	0.35
Liguria	0.05	1.51
Lombardia	0.04	0.37
Marche	0.04	0.28
Molise	0.00	0.40
Piemonte	0.04	0.40
Puglia	0.02	0.20
Sardegna	0.18	0.78
Sicilia	0.17	1.55
Toscana	0.05	0.55
Trentino-Alto Adige	0.03	0.33
Umbria	0.15	1.46
Valled'Aosta	0.31	3.78
Veneto	0.03	0.18
National average	**0.06**	**0.67**

Source: Authors' calculations based on TEC-FRAMESBS data and Alessi and Battiston (2022). Note: To make the index values more readable despite their small magnitude, they have been multiplied by 1000.

Table A4. Top Export Sector for the Top and Bottom 10 Provinces and Related Sectoral Alignment/Vulnerability Values

Province	ATECO Code	ATECO Name	TAC	TEC	Sector Weight on Total Exports
MI	1920	Manufacture of Refined Petroleum Products	0	1	7%
VV	2410	Iron and Steel Industry	0.05	0.5	0%
BS	2410	Iron and Steel Industry	0.05	0.5	7%
VI	2410	Iron and Steel Industry	0.05	0.5	4%
TV	2420	Manufacture of Tubes, Pipes, Hollow Profiles and Related Steel Fittings	0.05	0.5	1%
BG	2420	Manufacture of Tubes, Pipes, Hollow Profiles and Related Steel Fittings	0.05	0.5	5%
FI	2444	Production of Copper and Semi-finished Products	0.03	0	2%
MO	2910	Manufacture of Motor Vehicles	0.02	0.97	27%
BO	2910	Manufacture of Motor Vehicles	0.02	0.97	13%
TO	2910	Manufacture of Motor Vehicles	0.02	0.97	39%
CZ	3012	Building of Pleasure and Sporting Boats	0	1	13%
RM	3030	Manufacture of Aircraft, Spacecraft and Related Devices	0	1	23%
CL	3832	Recovery and Sorting of Materials	1	0	7%
IS	4211	Construction of Roads and Highways	0	0.98	3%
CS	4511	Sale of Cars and Light Motor Vehicles	0	0.98	4%
PZ	4511	Sale of Cars and Light Motor Vehicles	0	0.98	6%
EN	4531	Wholesale and Intermediation of Motor Vehicle Parts and Accessories	0	0.98	0%
OR	4671	Wholesale of Solid, Liquid, Gaseous Fuels and Related Products	0	1	0%
KR	4941	Road Freight Transport	0.002	0.998	1%
NU	4941	Road Freight Transport	0.002	0.998	0%

Source: Authors' calculations based on TEC-FRAMESBS data and Alessi and Battiston (2022).