

Analyzing Innovation through Bibliometrics: A Comparative Study of Sustainable Practices in Leading Economies

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Abstract. *This research is initiated by analyzing the post-pandemic period through digitalization and economic growth. In this research, we reopened the topics such as digitalization, sustainable development, and innovation. This research has also brought new sustainable development horizons, particularly in Europe. We are investigating the significance of innovation and research in pursuing sustainable development and digitalization in the social impact of economic innovations. It also examines specific innovative solutions that have positively impacted sustainable development. It marks a new phase with a gradual shift towards a retrospective analysis of COVID-19. For example, Switzerland has implemented a comprehensive recycling program. Federal measures to promote the circular economy are based on the principles of precaution and “polluter pays”, technological progress and innovation, and cooperation with industry under the Law on environmental protection. Sweden has pioneered renewable energy solutions; the country boasts seven municipalities that are 98% fossil-free. The UK has introduced innovative financial instruments to support green investments. This phase assessed how economic recovery and sustainability initiatives were influenced in these nations, considering their advanced level of innovation and ability to implement innovative solutions to post-pandemic challenges. This interest is demonstrated through increased resource allocation and support for initiatives that foster technological progress and sustainability, indicating a clear trend toward integrating innovative solutions into economic strategies. It delves into how these countries have balanced and incorporated these elements in the aftermath of the pandemic, highlighting specific strategies and outcomes in each case of countries. This research, bolstered by bibliometric analysis, underscores the importance of innovation in navigating the complexity of post-pandemic economic recovery and sustainability and compares leading nations. This research thoroughly delves into how countries have balanced and incorporated various elements in the aftermath of the pandemic. It meticulously highlights specific strategies and outcomes in each case, using bibliometric analysis to emphasize the importance of innovation in navigating post-pandemic economic recovery and sustainability. It compares the approaches and achievements of leading nations, providing insights into how innovation has driven their progress during this challenging period. This research looks at the effects of regional crises, such as the European debt post-pandemic destabilization, on economic environments through digitalization and the sustainable economy. For instance, the pandemic led to a significant decline in tourism revenue in Switzerland, a disruption in global supply chains for Sweden, and a decrease in foreign direct investment in the United Kingdom. Thus, following these goals, many beneficial reforms emerged. Our exploration into how innovation and research drive sustainable development and impact society through economic advancements is an ongoing journey. By analyzing the innovation indicator (GII 2023), this study highlights the critical importance of blending innovative research with economic policies to boost resilience and adaptability as the world shifts to a post-pandemic reality. This study spotlights the social dimensions of financial innovation and explores how sustainable practices can help alleviate*

unemployment, inequality, and other socioeconomic gaps while fostering a circular economic culture. It delves into how these practices foster a circular economy mindset and provide practical frameworks for sustainable economic development growth in a post-pandemic world.

Keywords: sustainable development, technological innovation, the economic impact of COVID-19, bibliometric analysis, Global Innovation Index (2023), economic resilience.

Introduction

In the post-pandemic era, the role of research, innovation, and digital transformation in enhancing sustainable economic development and the financial performance of companies has been brought to the fore and debated mainly by economists, practitioners, and policy-makers who render global the keen need for a comprehensive understanding in this scientific field (Pirtea et al., 2015; Noja and Panzaru, 2021). We focused on Switzerland, Sweden, and the UK because they do well in the Global Innovation Index.

After the global COVID-19 pandemic, we are genuinely interested in how the economy, technology, and sustainability work together.

After the global COVID-19 pandemic, which caused several restrictions and economic bottlenecks, people have begun to pay particular attention to technological progress and sustainability dynamics. This can be seen with recent global economic challenges—the Ukrainian war and rising gas prices in Europe show barriers.

The paper addresses the specific economic challenges of the current period, offering innovative, sustainable solutions. This article explores the circular economy and sustainable business models and presents novel approaches for mitigating unemployment and reducing inequalities. It underscores the necessity of a holistic and transdisciplinary perspective to navigate the complexities of globalization's branches effectively.

Finally, this study aspires to contribute significantly to the academic literature and the ongoing conversation on the concerned subjects while providing valuable directions for policy formulation and practitioners in sustainable economic development.

Literature review

The role of innovation and research in sustainable development

The level of innovative activity indicates the dynamics of a state's commitment to sustainable development. This is an indispensable critical global need and its ability to remain relevant. Innovations are fundamental instruments for manufacturing high-tech products and technological improvement in industries. International organizations and agencies are developing this subject deeply, presenting increasing evidence in academic and scientific spheres and urging us to act responsibly for a sustainable future.

Research on innovation within countries is pertinent for numerous international agencies and organizations. These entities offer their indices to gauge innovative activity across nations worldwide. Thus, the World Intellectual Property Organization publishes the Global Innovation Index annually. Switzerland occupies the first spot as the worldwide leader in innovation for the 13th consecutive year, according to the Global Innovation Index (GII) 2023. Launched in 2007, the Global Innovation Index (GII) was designed to identify and determine metrics and methods capable of offering society's most complete and comprehensive representation of innovation.

Second, the definition of innovation has been thoughtfully expanded; it is no longer limited to research and development (R&D) laboratories and published scientific papers. The concept of

innovation has become more general and horizontal, now including social, business model, and technical aspects. Now, in its 16th edition, the GII contributes to creating an environment where innovation factors are subject to continuous evaluation. Focusing on refining innovation policies, we examined several policymakers, detailed metrics, and a database relevant to the post-pandemic period.

Hence, a particular emphasis is placed on measuring the climate and infrastructure for innovation and assessing associated outcomes. In this context, Switzerland maintains its position as the global leader in innovation for the 13th consecutive year, according to GII 2023. Sweden has climbed second place in the GII 2023, surpassing the United States. Sweden's innovation landscape is robust and dynamic, with top positions for researchers and knowledge-intensive employment. The United Kingdom ranks fourth in the GII 2023, indicating a strong performance in innovation. However, the cited segments did not provide specific details regarding its leading sectors or indicators.

The recent regional crises: The impact is explored using data on the most highly developed countries through the 2030 Agenda for Sustainable Development.

The pandemic has profoundly impacted the economic and health domains, engendering negative repercussions that obstruct the trajectory toward achieving the SDGs by directly affecting livelihoods and global health outcomes.

As such, this backdrop presents an analysis point for understanding the compounded effects of recent regional crises and the pandemic on pursuing the SDGs, focusing on countries like Switzerland, Sweden, and the United Kingdom. The analysis aims to explore how these crises have affected specific Sustainable Development Goals in these countries. It looks into goals like ensuring affordable and clean energy (SDG 7), promoting decent work and economic growth (SDG 8), and taking action on climate change (SDG 13). Thus, by analyzing the evolution of the innovation indicator dynamics, which align with economic growth, we highlight and better perceive the adaptation of the countries affected by the pandemic and the armed conflict in Ukraine.

The Office for National Statistics monitors national performance within the United Kingdom against the 232 indicators delineated by the SDGs. In alignment with international commitments, the British government documents progress towards these objectives through the publication of periodic reports, a notable instance being the Voluntary National Review (VNR) of June 2019. In discussions with the Committee, the Secretary of State acknowledged a "nervousness" around governmental self-assessment for International Development.

The VNR analysis revealed that:

- Approximately 17% of the United Kingdom's population faces the risk of poverty within households.
- The adult mortality rate attributed to air pollution in England stands at 5.06%.
- A percentage of 11% of individuals aged 16 to 24 are unemployed and are not engaged in any education or training.
- 19.9% of homes in England do not meet the minimum standard to be considered "decent homes."

Beyond governmental efforts to monitor the SDGs, various organizations assess progress, including the UK Partnership for Sustainable Development (UKSSD). An analysis conducted by UKSSD in 2018, with contributions from the Institution of Civil Engineers (ICE), found that, of the 143 objectives relevant to fulfilling the SDGs in the United Kingdom, there is satisfactory

performance for 24% of them. However, gaps in policy or inadequate performance for 57% of the objectives were identified, with a significant policy deficit or poor performance of 15%.

In analyzing the repercussions of recent regional crises and the COVID-19 pandemic on economic and sustainable development, particularly honing in on fluctuations in natural gas prices and the conflict in Ukraine, the United Kingdom emerges as a case study characterized by resilience and challenges.

Economic growth projections are continuously subdued, with an anticipated expansion of just 0.4 % in 2023, followed by a slight improvement to 1 % in 2024. This scenario is further compounded by a terms-of-trade shock amidst a historically tight labor market, propelling inflation to unprecedented heights.

In response, the UK's monetary authorities have implemented a stringent monetary policy adjustment, highlighted by a 50-basis-point increment in interest rates as of June. Fiscal measures have also been intensified in the battle against inflation. The review of the UK economy's post-pandemic dynamics identifies specific structural barriers, including a current potential growth rate of approximately 1.5%. The COVID-19 pandemic, the armed conflict in Ukraine, and Brexit influenced the significant changes in the British state in 2020.

Additionally, the labor supply has only recently reverted to its pre-pandemic levels, displaying a weaker recovery than its peers. Mirroring trends in other advanced economies, the UK has experienced sluggish productivity growth, reflecting decelerated innovation and technological dissemination rates.

Despite Switzerland's standing as a nation with one of the highest productivity levels among OECD members, productivity growth has decelerated over the last thirty years. This slowdown emerges as a pivotal concern, particularly in mitigating the demographic impacts of an aging population on the per capita GDP. This scenario underscores a shared challenge among advanced economies, including Switzerland and the United Kingdom, highlighting the nuanced repercussions of the pandemic, regional geopolitical tensions, and economic disturbances on sustainable development and financial resilience. The insights are significant for understanding the impact of recent regional crises and the pandemic on economic and sustainable development. They emphasize the need for adaptive reforms and improved labor market inclusivity to navigate the post-crisis recovery phase.

The Swiss economy has demonstrated resilience in the pandemic, yet uncertainty and challenges persist. Governmental support has effectively protected jobs and sustained household incomes; however, specific sectors and demographic groups have experienced disproportionate impacts, highlighting the difficulties faced by workers with modest qualifications and wages. Deregulation and enhancing domestic and international competition revitalize competitive pressures and boost productivity and economic development.

Switzerland's GDP decreased by 2.5% during the initial phase of the COVID-19 pandemic due to global economic destabilization. Over time, inflation from its robust position followed a downward trend, with record results, thus having an inflation index of 1.1% in the last period. Therefore, we can see that the financial destabilization of Switzerland, starting with the COVID-19 period, was caused by international fluctuations, including trade disruptions and disruptions in the supply chain. National isolation strategies have influenced domestic demand, disproportionately affecting non-export-oriented sectors, such as services, more significantly than those geared toward international transactions. Indicators such as the Purchasing Managers' Index (PMI) and other measures of economic outlooks by sector suggest a confirmation of this phenomenon. For instance, in Sweden, the contraction of service sector activity between February

and April, though notable, was considerably more contained compared to trends observed in other European nations.

Economic challenges have adversely affected the Swedish economy, leading to a recessionary trend in 2023. This analysis is derived from the Ministry of Finance's latest prognostications.

The Ministry of Finance projects a contraction of Sweden's Gross Domestic Product (GDP) by 0.8 % for the current year.

Notably, there has been a slight deceleration in inflation rates recently, a trend observed both within Sweden and internationally. Nonetheless, given the economic regression, an uptick in unemployment rates is anticipated in 2024.

Additionally, the Swedish manufacturing sector, primarily oriented towards exports, was significantly impacted, in line with the dynamics of production PMI that began to decline in March, a trend aligned with the experiences of other European countries. This reflects a decrease in external demand and supply chain disruptions independent of the nation's isolation policies.

These factors and a considerable decline in labor force employment in recent weeks suggest that isolation strategies may influence quarterly rather than annual economic growth. Experts agree that Sweden will face a profound recession this year. Yet, it is premature to determine whether the adopted approach will extend the recession period or facilitate economic recovery.

Methodology

To explore the ramifications of recent regional crises, such as the surge in natural gas prices at the European level and the consequences of the Ukraine conflict, on sustainable development while highlighting the pivotal role of innovation and research in Switzerland, Sweden, and the United Kingdom, a bibliometric research strategy was employed. This approach enabled a structured review and assessment of the pertinent academic contributions, facilitating a detailed overview of innovation and sustainable development trends. VOSviewer, software designed for visualizing bibliometric networks, was utilized to analyze and depict these trends, thus enhancing our in-depth investigation of the topic.

The study commenced with establishing selection criteria for scientific publications, prioritizing works from the post-pandemic era (2020-2023) that delve into sustainable development, innovation, and the repercussions of the COVID-19 pandemic. Esteemed academic and research platforms, including Web of Science, Scopus, and Google Scholar, served as the sources for data compilation.

Leveraging data from the Global Innovation Index, Switzerland, Sweden, and the United Kingdom were identified as the top three European innovation leaders. The subsequent bibliometric analysis scrutinized the distribution of research across these regions, citation frequencies, co-authorship dynamics, and prevalent keywords. Through this methodology, the study sheds light on the leading trends and scholarly focus within sustainable development and innovation amidst the backdrop of the latest regional crises and the impact of the pandemic.

Research Questions:

- What was the impact of the COVID-19 pandemic on the progress toward sustainable development goals in Switzerland, Sweden, and the United Kingdom in the context of their leadership positions in the Global Innovation Index (2023)?

- In what specific ways have technological and environmental innovations in these countries contributed to the advancement of sustainable development in the post-pandemic period? How did the escalation of natural gas prices and the Ukraine conflict, alongside the COVID-19 pandemic, affect the pursuit of sustainable development goals within the innovation-leading nations of Switzerland, Sweden, and the United Kingdom?
- What innovative approaches and sustainable solutions can be identified in these nations' responses to specific post-pandemic economic challenges, such as unemployment and inequality, through the lens of the circular economy and sustainable business models?

Results and discussions

Our analysis of bibliometric research is comprehensive and uses VOSviewer to identify and visualize co-authorship networks, frequently used keywords and geographical research distribution.

This enables us to examine the co-occurrence of keywords, isolating those terms that have predominated, appearing at least twice in the articles analyzed. Consequently, we have identified central thematic nodes such as “Development”, “Technological innovation”, “Covid”, “Sustainable development”, “Switzerland”, “Sweden”, and “United Kingdom.”



Fig. 1. Co-occurrence of keywords specific to the themes Development-Technological innovation- Switzerland

Source: Own research in VOSviewer.

Adjacent to the central nodes, terms such as “Environmental management”, “Human”, and “Employment” appear as salient themes, reflecting an interdisciplinary approach in the literature that intersects human capital, labor dynamics, and ecological considerations within the ambit of technological progress.

Keywords like “Biomedical research” and “Automotive industry” adjacent to the central thematic node indicate sector-specific studies that are integral to Switzerland's innovative ecosystem, highlighting the country's diversified strengths in life sciences and engineering.

Moreover, peripheral terms such as “Feasibility studies”, “Cross-disciplinary research”, and “Empirical studies” denote methodological approaches prevalent in the research, which underscore the empirical rigor and exploratory nature of innovation-related academic inquiries.

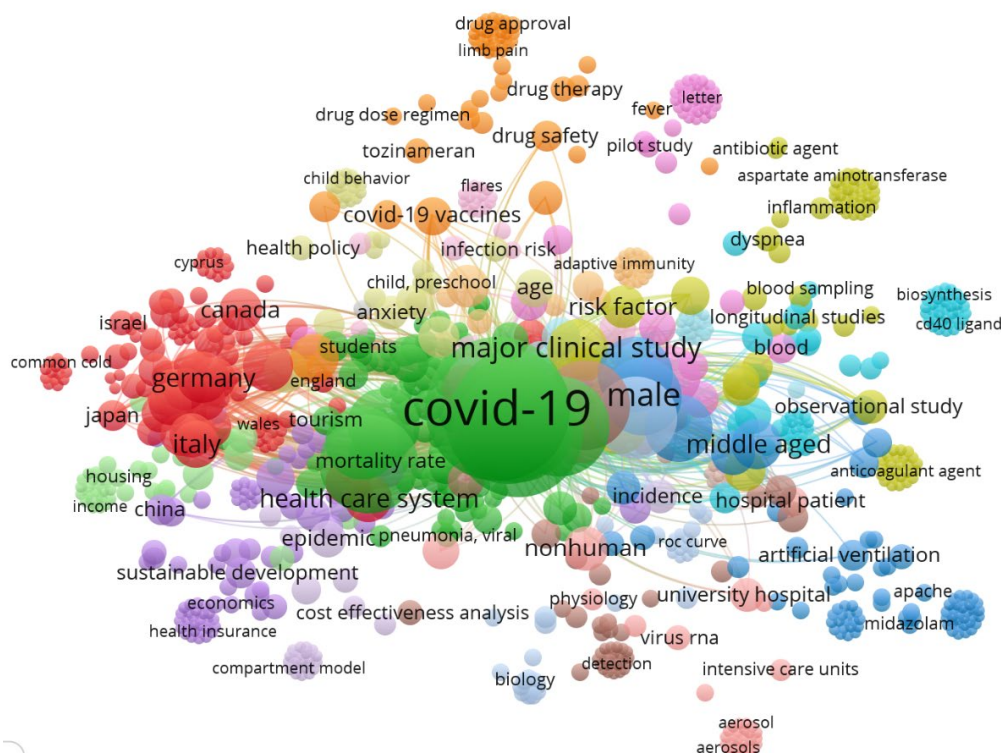


Fig. 2. Co-occurrence of keywords specific to the themes Covid-Sustainable development- Switzerland

Source: Own research in VOSviewer.

Figure 2 presents a bibliometric visualization depicting the co-occurrence of keywords within the interconnected thematic realms of COVID-19, sustainable development, and Switzerland's specific context. The graphical schema, as rendered by VOSviewer, illustrates the multifaceted research landscape shaped by the ongoing pandemic.

Adjacent to this, the convergence of “Sustainable development” with “Economics” and “Health insurance” suggests an academic inquiry into the economic implications of the pandemic and the pursuit of resilience and sustainability in health financing. Furthermore, the integration of geographical nodes such as “Switzerland”, “Germany”, and “Italy” alongside “COVID-19” indicates a significant concentration of research output from these nations, likely due to their varied experiences and policy responses to the pandemic.

The presence of methodological terms such as “Major clinical study”, “Observational study”, and “Longitudinal studies” points to the rigorous research designs employed to unpack the complex interactions between the pandemic's health impacts and socioeconomic outcomes.

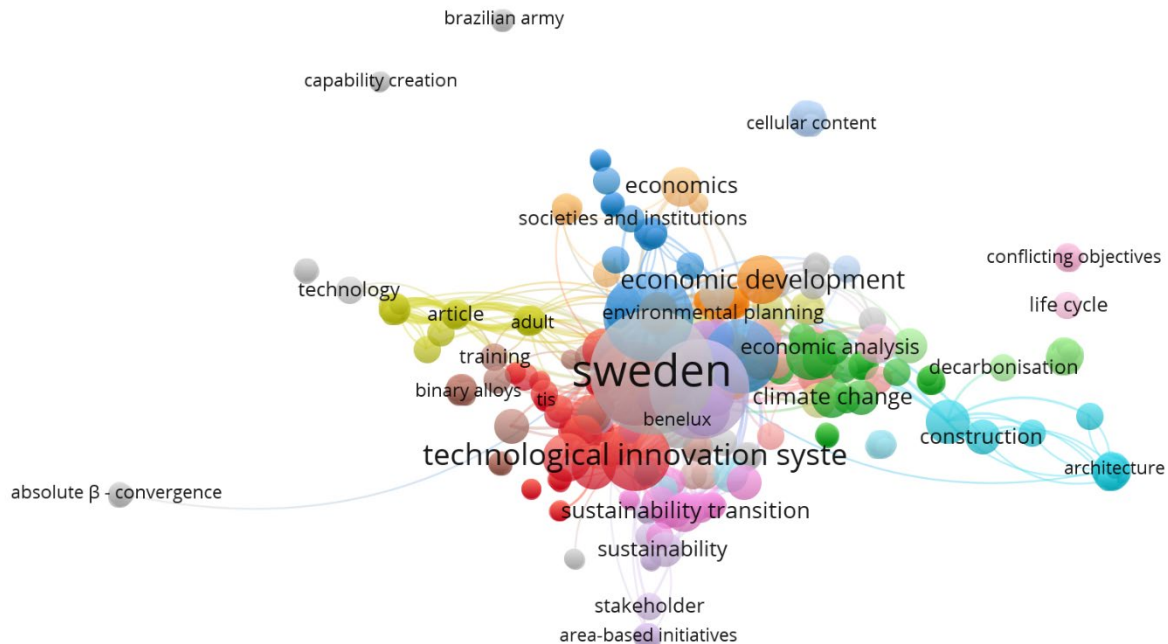


Fig. 3. Co-occurrence of keywords specific to the themes Development-Technological innovation-Sweden

Source: Own research in VOSviewer.

Figure 3 offers a bibliometric visualization that captures the co-occurrence of keywords central to “Development”, “Technological innovation”, and “Sweden.” The VOSviewer-generated map showcases the relational dynamics among these themes within the scholarly discourse. The salient cluster around Sweden indicates the country's prominent research focus, particularly concerning the “Technological innovation system”, suggesting an advanced state of systemic innovation that aligns with Sweden's reputation as a leader in embracing and fostering technological advancements.

Adjacent to this, the convergence of “Sustainability transition” and “Economic Development” with Sweden underscores the integration of sustainable practices within the framework of economic progress. This suggests that Swedish economic policies are being scrutinized for their capacity to foster sustainable growth, especially within the context of “Climate change” and “Decarbonisation”—terms that are notably proximal to “Sweden” within the network. The linkage of “Economic analysis” with “Environmental planning” and “Construction” reflects a research trend toward evaluating the economic implications of environmental strategies and the sustainable planning of infrastructures.

Moreover, “Societies and institutions” within the network hint at the socioeconomic structures underpinning innovation systems. The term “Inclusive development” situated within the network suggests an acknowledgment of the need for broad-based benefits of technological progress, ensuring that innovation leads to societal benefits that are equitably distributed.

Source: Own research in VOSviewer.

Integrating “Sustainable development” within this context suggests an academic contemplation on the pandemic's implications for long-term sustainability goals. The juxtaposition of “COVID-19” with “Economics” and “Investment” reflects a scholarly investigation into the pandemic's economic shocks and the subsequent financial strategies implemented to mitigate these impacts. Furthermore, the spatial keyword “Sweden” within this map is linked to “Public health” and “Economic” nodes, implying a region-specific analysis of the pandemic's ramifications, which may encompass Sweden's healthcare response, economic resilience, and policy adaptations in the face of COVID-19.

DOI: 10.2478/picbe-2024-0227, pp. 2719-2732, ISSN 2558-9652 |
Proceedings of the 18th International Conference on Business Excellence 2024

Source: Own research in VOSviewer.

The prominence of words such as “Innovation technological” in close association with the UK highlights the country's significant impact on technology advancement in different sectors, as evidenced by adjacent nodes, such as innovation, “Product”, “Engineering”, and “Technological policy.”

Keywords like “Economic growth”, “Research”, and “Economic geography” highlight the analytical focus on the spatial and economic dimensions of innovation, including the dissemination of knowledge (Knowledge spillovers) and regional differentiation within the UK, as indicated by references to Scotland and Wales.

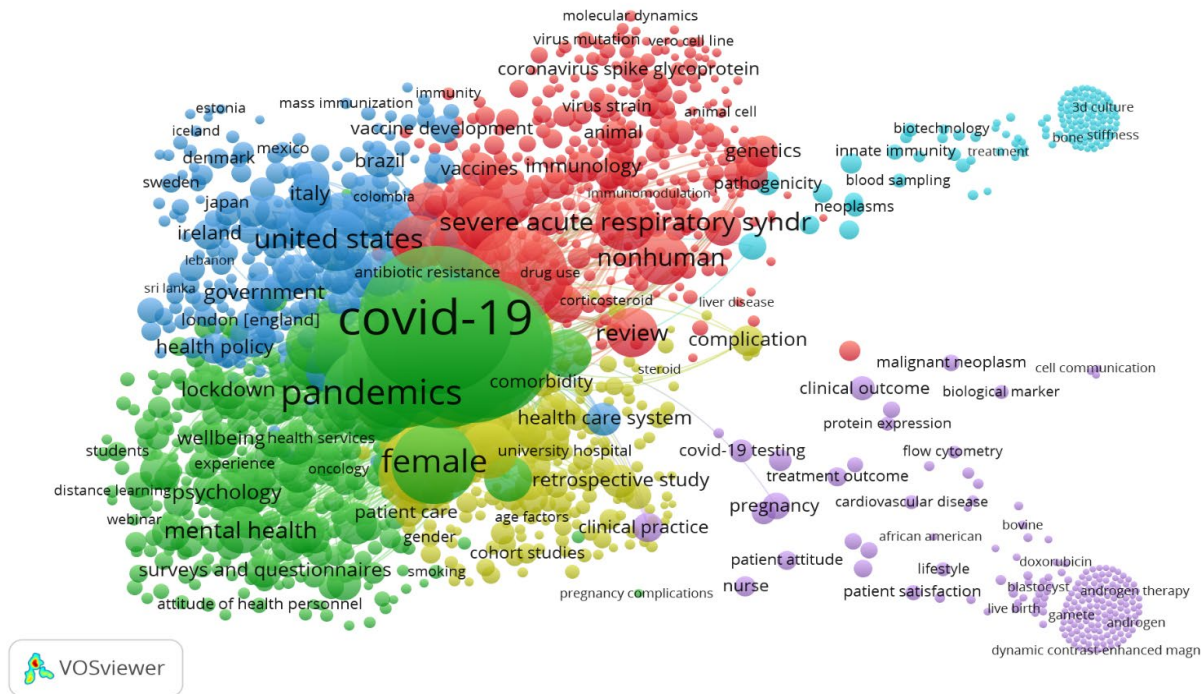


Fig. 6. Co-occurrence of keywords specific to the themes Covid-Sustainable development-United Kingdom

Source: Own research in VOSviewer.

Figure 6, as rendered by the bibliometric tool VOSviewer, delineates the co-occurrence of keywords intricately associated with COVID-19, sustainable development, and the United Kingdom. The visualization reveals a dense network of interconnected terms, capturing the breadth and depth of academic inquiry into these critical areas. Central to the network is COVID-19, symbolizing the pandemic's overarching influence on contemporary research. The proximity of terms such as “Pandemics”, “Health policy”, and “Government” to “COVID-19” reflects the extensive exploration into public health responses and governmental strategies to manage the crisis, particularly within the context of the United Kingdom.

Integrating two distinct analyses—bibliometric mapping via VOSviewer and examining natural gas prices in the European Union—provides a multifaceted view of the contemporary challenges facing sustainable development and public health policy amid COVID-19 and energy crises.

From the bibliometric perspective, the analysis generated by VOSviewer illustrates a complex network of keywords linking COVID-19 with sustainable development and the public health response, particularly emphasizing the situation in the United Kingdom, Sweden, and Switzerland. This visual portrayal emphasizes the widespread impact of the pandemic on research, emphasizing essential academic priorities like pandemic management, health policy, and government strategies.

Concurrently, the natural gas price dynamics in the European Union during the first half of 2023 reveal critical economic challenges, particularly for medium-sized household consumers. With prices reaching their zenith in countries like the Netherlands, Sweden, and Denmark, the scenario unfolds a stark disparity in energy costs across the EU, with the Netherlands experiencing

rates substantially higher than the EU average and significantly above those in Hungary, Croatia, and Slovakia.

This situation has unfolded against increasing energy prices over the years, exacerbated by the recent surges from 2022 onwards. These surges departed from the usual seasonal pricing trends and set new records for natural gas prices.

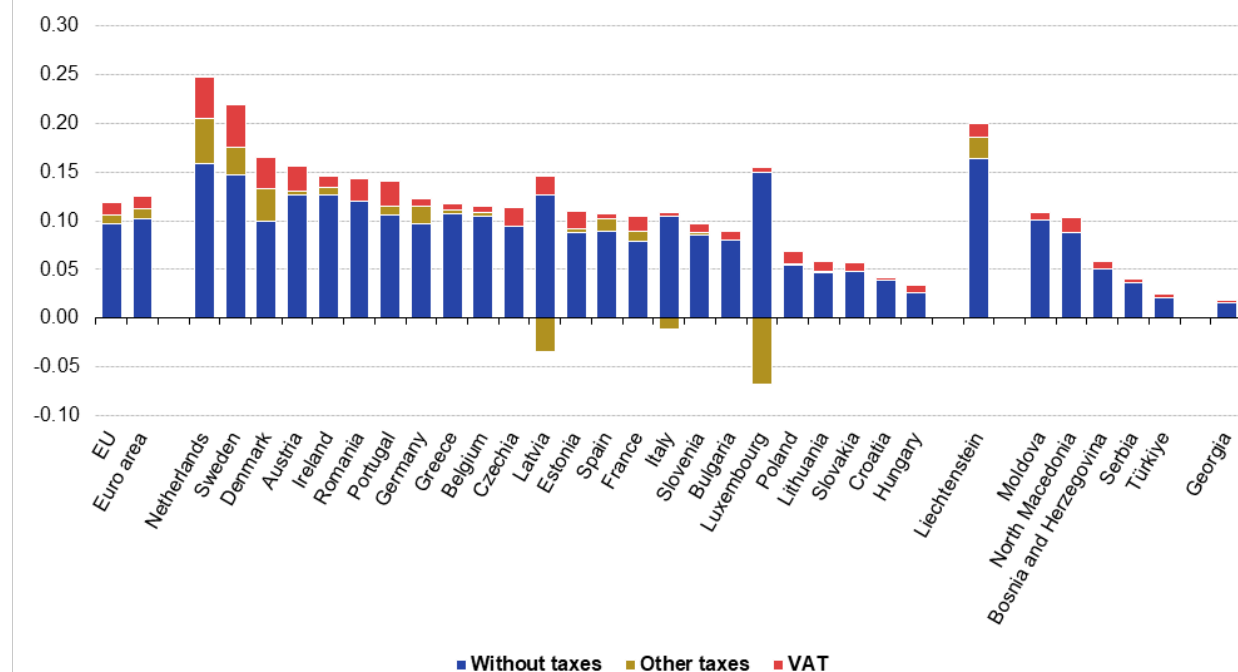


Fig. 7. Natural gas prices for household consumers, first half 2023

Source: Eurostat (2024).

Though significantly higher than the EU average, the depicted prices within Sweden reflect a composite of underlying tax structures and the market's response to escalating regional tensions and supply disruptions. The United Kingdom and Switzerland, while not graphically represented here, have also experienced unique pricing dynamics, likely influenced by similar geopolitical and economic factors, though potentially mitigated by distinct national policies and energy strategies.

Following the bibliometric analysis, we note that the European energy market countries have become more sensitive to the Ukraine war. The impact of regional crises on household energy costs can be directly economic, potentially impacting consumer behavior and broader financial conditions. This could challenge these nations' sustainability efforts, as higher energy costs may inhibit or complicate the transition to more sustainable energy systems or burden households, thereby impacting discretionary spending and economic stability.

Considering the significant regional crises, notably the escalation in natural gas prices across Europe and the ongoing conflict in Ukraine, the focus on healthcare systems, patient care, and clinical practices has been sharply reevaluated within the COVID-19 pandemic context. This evaluation highlights the critical importance of sustainable development within health service research, suggesting that effective crisis management must incorporate sustainable health and economic strategies.

The bibliometric analysis, framed by the 6th edition of the GII, navigated these challenges by ensuring data reliability and methodological precision.

VOSviewer's superior visualization capabilities, compared to methods such as co-word analysis, simplify the interpretation of complex bibliometric information, providing explicit, user-friendly graphical representations.

In the European Union, targeting medium-sized household consumers with yearly usage between 20 and 200 Gigajoules, the initial half of 2023 saw the highest natural gas prices in the Netherlands, Sweden, and Denmark, with the lowest rates found in Hungary, Croatia, and Slovakia. Specifically, Dutch households faced a gas price of €0.2481 per Kilowatt hour (kW), over seven times that in Hungary (€0.0337 per kWh) and 157% above the EU's average (€0.1187 per kW).

The EU's average natural gas price for household consumers, based on the most recent data from early 2023, stood at €0.1187 per kW, marking a significant increase.

A longitudinal view of EU household natural gas prices since mid-2008 reveals a general trend of higher rates in the latter half of each year, a pattern typically influenced by seasonal demands. Traditionally depicted in a zig-zag pattern in the data, this trend has been somewhat leveled due to pronounced price surges starting from the first half of 2022 and persisting into 2023. From a low in early 2010 at €0.0562 per kW, prices saw a peak in early 2013 at €0.0692 per kW, followed by fluctuations until a dramatic increase to €0.1187 per kW in early 2023 from €0.0861 per kW the preceding year, marking a record high since the commencement of this data series.

Tax proportions, which had risen from 25% in early 2008 to 36% by early 2021, dropped to 19% by early 2023, reflecting governmental interventions to mitigate the impact of soaring energy costs. Prices before taxes in early 2023 (€0.0964 per kW) fell below those in late 2022, indicating a return to the pre-2022 seasonal pricing trend.

Conclusion

One significant limitation pertains to the timeliness of the data incorporated within the index. The GII endeavors to utilize the most recent data available; however, the distribution of these data spans from the report's publication year back to 2013. This variability in the currency of data introduces a time-lag challenge, potentially delaying the reflection of recent developments and innovations within the economies in question.

The inclusion criteria, necessitating data for at least 36 indicators in the Innovation Input Sub-Index and 17 in the Innovation Output Sub-Index, resulted in the exclusion of 61 economies due to insufficient data.

Furthermore, the GII's approach to missing values, where such values are not estimated but marked as "n/a" and excluded from the scoring process, emphasizes transparency and replicability. The robustness of the GII's modeling choices has been assessed through audits conducted by the European Commission's Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC-COIN).

The GII uses fissurization to address outliers in its dataset, minimizing the impact of extreme values on the overall data distribution.

However, it also means that some genuine variations within the data might be suppressed, possibly overlooking significant, albeit rare, innovations or trends.

Index findings should be interpreted with these limitations—data currency, handling of missing values, and handling of aberrant values—in mind. This technique is required to reduce the possibility of bias that outliers could inject into the rankings.

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