Green Alliance in Demographic Crisis: Sustainability Challenge of EU–Japan Green-Growth Cooperation amid Japan's Shrinking Workforce Population

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Abstract. Japan's aging and shrinking workforce may constrain the implementation capacity of the EU–Japan Green Alliance and its goals for decarbonisation, green innovation, and sustainable growth. This study examines how Japan has responded to demographic pressure and assesses the effectiveness of these responses for sustaining green-growth cooperation. Using an explanatory qualitative case-study design, the research relies on policy documents, demographic statistics, international-organisation publications, and relevant academic studies. The findings identify three main responses: strengthening domestic human capital through R&D, STEM, and vocational training; supplementing labour supply through selective immigration; and substituting labour through digital technologies, robotics, and automation. These measures help preserve innovation capacity and support green transformation, but remain only partially effective in meeting the quantity and skills required in emerging green sectors. The Green Alliance therefore depends not only on technology and diplomatic commitments, but also on labour availability, skills, and institutional capacity.

Keywords: Green Alliance, Green Growth, Japan Depopulation, Human Capital, European Union

1 Introduction

The EU–Japan Green Alliance is pivotal to global green diplomacy as it links two major industrial players, Japan and the EU, both aiming for carbon neutrality by 2050. The partnership, instituted in 2021, is not just aimed at environmental collaboration, but provides the structure for the partnership to include the development of low-carbon technologies, alignment of regulatory frameworks, joint research and collaboration in sustainable finance and the protection of biodiversity. From the outset, the partnership has gone further than the usual political declarations and developed the collaborative processes to support the gradual reduction of public support for carbon-heavy fossil investments, international green financing, and collaborative global governance of plastic. For these reasons, the Alliance is both a bilateral decarbonization initiative and an experimental arena for international green standards and normative construction in the Asia Pacific and beyond [1, 2, 3, 4]. Japan has a significant structural constraint due to its demographic trends and rapid aging and depopulation, with a peak of 128 million in 2008-2010, predicted to fall to 97 million by 2050. Japan's working-age population is rapidly declining and is accompanied by a growing elderly demographic. Earlier estimates suggested Japan's population stratified into 15-64 years of age (59.5%) and 65 years

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and older (28.6%) by 2021, projecting a loss of 20 million people of working age from 2020-2050. This creates a significant and enduring demographic shift and a substantial long-term decrease in labor supply [5, 6].

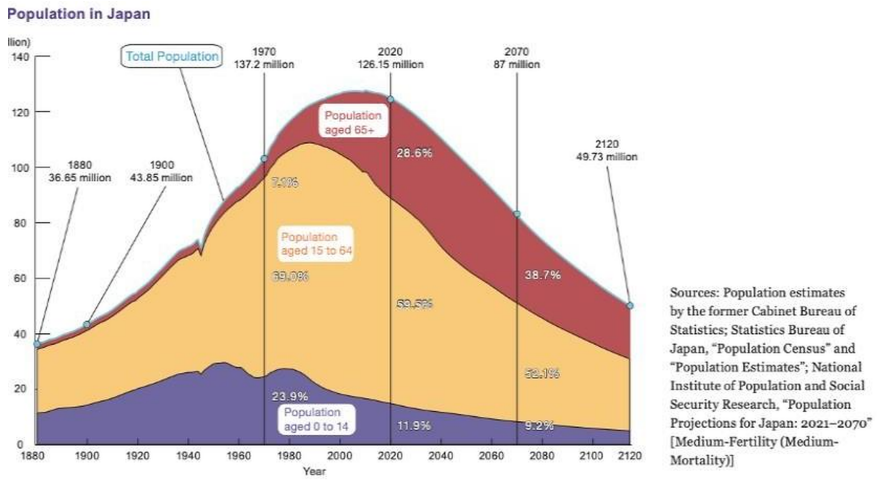


Fig. 1. Historical and Projected Population of Japan, 1880–2120

Source: National Institute of Population and Social Security Research (2024) [5].

Figure 1 demonstrates that Japan's post-war demographic expansion has reversed into a sustained contraction. Figure 1 shows that the decrease impacts the total size of the working-age population and the younger population. This has significant implications for long-term economic and policy capacity. The demographic problem is particularly relevant to green growth because green transition is not driven by targets alone. It requires skilled labor, technological adaptation, sectoral coordination, and a workforce capable of supporting renewable energy, energy efficiency, green manufacturing, and clean innovation. This is why the declining working-age population should be treated as a primary constraint on implementation capacity. In Japan's case, labor scarcity is already evident in green transition related sectors. In 2022, 82% of surveyed manufacturing employers reported difficulty finding workers with the required skills [46]. Other sectors, including IT and technology, education, health and government, and construction report severe labor shortages. These patterns suggest that Japan has not only a demographic problem, but also a capability problem in the precise sectors that are necessary to sustain a low-carbon transformation [7, 8]. The labor force trends become even clearer when placed in comparative perspective.

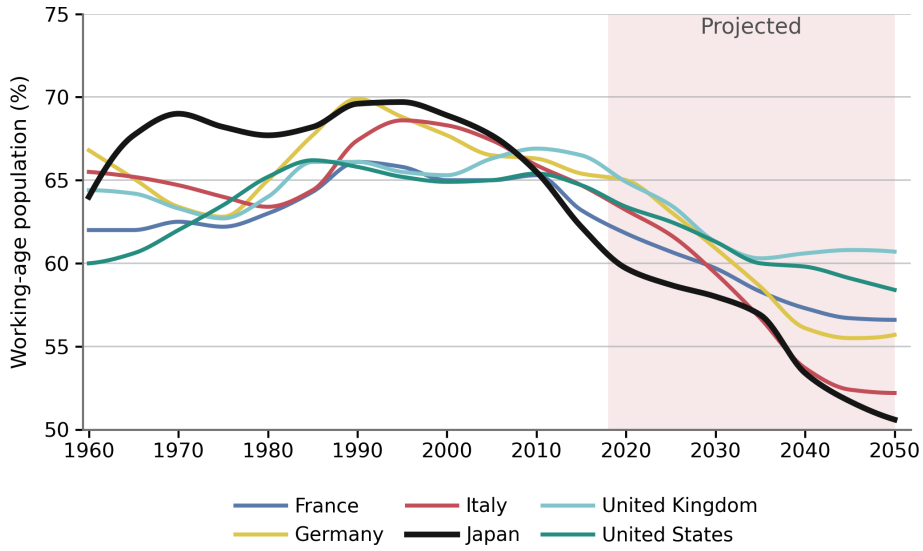


Fig. 2. Working-Age Population Share in Selected Economies, 1960–2050

Source: Redrawn from Schneider et al. (2018) [47]; underlying data: UN (2017) [48].

Figure 2 shows that the working-age share of Japan's population is projected to decline more sharply than in the other advanced economies shown. Based on Figure 2, Japan enters the green transition with a more acute demographic burden than many of its peers, which raises doubts about whether policy ambition is matched by sufficient implementation capacity. This tension between ambition and capacity explains why Japan has responded through R&D expansion, Society 5.0, STEM strengthening, vocational training, automation, and selective migration. Nevertheless, these responses remain partial rather than definitive. They may improve productivity and soften labour shortages, but they do not automatically resolve the long-term mismatch between green -sector demand and workforce supply.

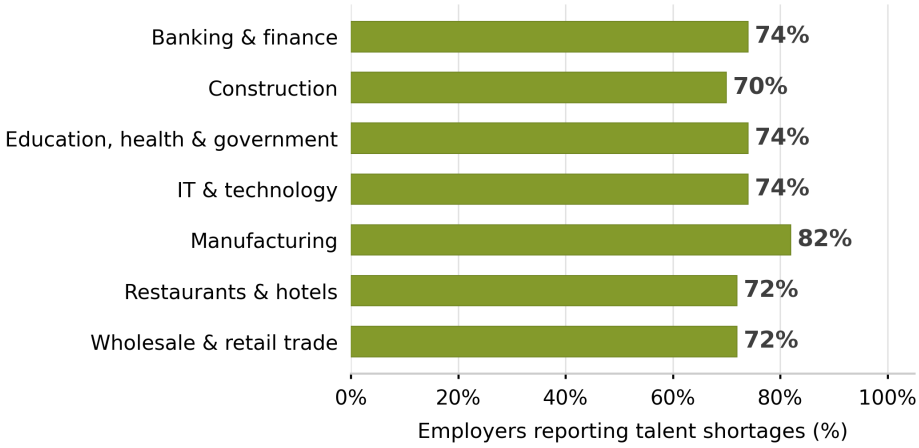


Fig. 3. Employers Reporting Talent Shortages by Sector in Japan (2022)

Source: Redrawn from ManpowerGroup (2022) [46]; also reported by Jayasuriya (2023) [49].

Figure 3 shows widespread employer-reported talent shortages across sectors relevant to green industrial transformation. Based on Figure 3, Japan's domestic bottleneck is not merely demographic decline in the abstract, but the weakening availability of labour in sectors essential to innovation, infrastructure, and technological deployment. Despite growing scholarship on the EU–Japan Green Alliance from legal and institutional perspectives, and a separate body of work on Japan's demographic crisis and labour-market adjustment, these literatures rarely intersect. Existing studies explain the alliance's normative design and cooperative significance, while demographic studies focus on ageing, labour shortages, migration, or productivity. What remains underexplored is how Japan's shrinking workforce affects the long-term implementation capacity of the Green Alliance itself. This article addresses that gap by arguing that the decline in Japan's working-age population risks weakening the supply of skilled labour, the pace of green innovation, and the policy execution capacity required to meet shared green growth commitments, while current responses such as automation, selective migration, and human capital investment offer only partial solutions [1, 4]. Against this background, the core problem is not merely Japan's demographic decline itself, but the extent to which the shrinking working-age population undermines the country's long-term capacity to implement the commitments embedded in the EU–Japan Green Alliance. This study starts from the observation that the EU–Japan Green Alliance has been framed as an ambitious platform for advancing decarbonization, green innovation, regulatory cooperation, and sustainable growth, yet its implementation depends heavily on domestic capacity within each partner state. In Japan, that capacity is increasingly shaped by a structural demographic crisis marked by population ageing and a shrinking working-age cohort. Although Japan has continued to promote green growth through technological upgrading, R&D investment, industrial transformation, and international environmental cooperation, the long-term sustainability of these efforts cannot be separated from the availability of skilled labour, adaptive institutions, and implementation capacity across key sectors. The problem, therefore, lies in a growing tension between external policy ambition and internal demographic constraint. Existing discussions have not sufficiently explained whether Japan's

declining workforce merely creates economic pressure, or whether it also poses a deeper challenge to the feasibility, pace, and continuity of bilateral green cooperation with the European Union. This unresolved tension makes it necessary to examine demographic decline not as a background condition, but as a structural variable that may directly weaken innovation capacity, policy execution, and the supply of green-skilled labour required to sustain the alliance's long-term objectives [1, 4]. Given this problem, the study must move beyond descriptive accounts of demographic change and explicitly assess how demographic pressure interacts with green cooperation capacity. Accordingly, this article aims to analyse how Japan has responded to the shrinking working-age population in order to sustain its role within the EU–Japan Green Alliance, and to evaluate the extent to which these responses are effective in supporting a sustainable green growth transition. More specifically, the study seeks to explain the relationship between demographic decline and the implementation of green cooperation by examining Japan's policy responses through labour adjustment, technological substitution, and human capital strengthening. In doing so, the article positions demographic change as a central analytical factor in understanding the practical limits of international green cooperation, particularly when ambitious environmental commitments are pursued under conditions of long-term labour contraction. This objective is aligned with the reviewer's concern that the paper should not remain merely descriptive, but should explain how and why depopulation affects the long-term effectiveness of Green Alliance implementation. To operationalise this analytical objective, the study is organised around two research questions: a. How has Japan deal with the problem of a shrinking working-age population so that it can keep contributing to the EU–Japan Green Alliance? b. To what extent are these strategies effective in meeting the labour, innovation, and policy demands of a sustainable green growth transition? The novelty of this study resides in its endeavour to connect two strands of scholarship that have predominantly developed in parallel yet seldom intersect. On the one hand, existing studies on the EU–Japan Green Alliance have primarily examined its legal architecture, institutional significance, and diplomatic role in global environmental governance. Conversely, the literature on Japan's demographic crisis has concentrated mainly on ageing, labour shortages, migration, and macroeconomic adjustments. This article contributes by integrating these two bodies of literature into a cohesive analytical discourse and by demonstrating that demographic decline is not merely a domestic socioeconomic concern, but a strategic impediment to the implementation of international green cooperation. Furthermore, the study provides a more specific contribution by addressing the declining working-age population. Additionally, this study makes a more specific contribution by treating the shrinking working-age population as a problem of implementation capacity, rather than just a general background variable. This article emphasises that the success of the Green Alliance relies not only on climate targets, technological aspirations, and bilateral commitments, but also on Japan's ability to maintain the labor, skills, and institutional resources required to convert green commitments into long-term policy outcomes. This renders the article analytically distinct from previous studies that examine either the alliance or the demographic crisis in isolation.

2 Previous Studies

2.1 Studies on EU–Japan Green Alliance

Most of the research that has been researched on the EU–Japan Green Alliance has looked at it as a legal, institutional, and diplomatic framework within the broader external projection of the European Green Deal. This literature generally emphasises the alliance's role in enhancing EU-Japan cooperation on clean energy, innovation, regulatory coordination, sustainable finance, and climate diplomacy, while also contextualising it within earlier cooperation frameworks such as the EPA and SPA [4, 9]. A number of studies further emphasise its significance for hydrogen cooperation, net-zero alignment, and the international diffusion of green norms and standards, particularly through the EU's external climate strategy and broader green diplomacy agenda [10, 11, 12]. Nonetheless, this body of research remains predominantly normative and institution-oriented. [10, 11, 12]. However, this body of research remains largely normative and institution-oriented. It pays much greater attention to the alliance's legal design, strategic ambition, and diplomatic meaning than to its concrete implementation after 2021, and it rarely examines the domestic capacity constraints on the Japanese side that may shape the long-term feasibility of these commitments.

2.2 Studies on Japan's demographic crisis and labour shortage

A separate and more extensive body of literature has analysed Japan's demographic crisis through the interconnected issues of ageing, depopulation, labour shortages, migration, and automation. These studies consistently demonstrate that the declining working-age population has emerged as a structural impediment to Japan's long-term economic performance, labour market stability, and productivity, while simultaneously exacerbating dependency pressures and intensifying shortages across various sectors. [13, 14]. In response, the literature commonly discusses migration policy, women's labour participation, delayed retirement, robotics, and AI as partial strategies for compensating for labour scarcity, although many studies conclude that these measures remain institutionally constrained, uneven in impact, or insufficient to fully offset the scale of demographic decline [15, 16, 17, 18]. Nevertheless, despite its richness, this literature largely treats Japan's demographic crisis as a domestic economic and social policy problem, rather than as a factor that may directly affect the country's capacity to sustain international green cooperation and implement long-term bilateral climate commitments.

2.3 Research gap and contribution of this study

The two strands of scholarship have developed largely in parallel: studies on the EU–Japan Green Alliance primarily examine legal architecture, climate diplomacy, clean energy cooperation, and the alliance's role in projecting green norms internationally, while studies on Japan's demographic crisis focus on ageing, depopulation, labour shortages, migration, and automation as domestic structural challenges. What remains insufficiently explored is how these two domains intersect, particularly how Japan's shrinking working-age population affects its long-term capacity to implement the commitments embedded in the Green Alliance. This gap is analytically significant because the effectiveness of green cooperation depends not only on diplomatic alignment and technological ambition, but also on the labour, skills, and institutional capacity required to carry out green transition policies in practice. This study

addresses that gap by bringing these previously separate literatures into a single analytical framework and by treating demographic decline not merely as a background condition, but as a concrete implementation-capacity problem for EU-Japan green growth cooperation. In doing so, the article contributes empirically by linking Japan's domestic labour constraints to the feasibility of sustaining bilateral green commitments, and analytically by reframing the Green Alliance as a cooperation framework whose long-term effectiveness depends on human capital, labour-market adaptation, and the limits of technological substitution under demographic pressure.

3 Theoritical Framework

3.1 Human Capital Theory

Human Capital Theory asserts that investments in education, training, and skills development augment individual productivity and serve as a fundamental driver of economic growth and structural transformation. [19, 20]. In the context of the transition toward a low-carbon economy, this perspective is particularly relevant because the development of green human capital, which includes technical, vocational, and adaptive skills, determines the capacity of the workforce to support emerging sectors such as renewable energy, environmental technologies, and sustainable industries [21, 22]. Empirical and theoretical studies consistently highlight that education systems, lifelong learning, and workforce training must be aligned with evolving labour market demands in order to facilitate effective technological adoption and environmental innovation [23, 24]. Moreover, human capital is not only a factor of productivity but also a central determinant of sustainability, as it shapes innovation, adaptability, and long-term resource efficiency [25]. However, although Human Capital Theory effectively explains the micro-level foundations of skills and productivity, it is less capable of addressing structural constraints such as demographic ageing and labour shortages, both of which may limit the availability and renewal of skilled workers over the long term. Therefore, this study employs Human Capital Theory as a foundational analytical lens to emphasize the importance of skilled labour in the green transition, while also recognizing the need to complement this perspective with broader approaches to demographic change and labour market dynamics.

3.2 Green Growth Perspective

The Green Growth perspective provides a macro-level framework that conceptualizes the transition to a low-carbon economy as a process of economic restructuring driven by innovation, policy coordination, and structural change. In this view, green growth is not limited to environmental protection but represents a strategy to simultaneously enhance economic performance and environmental sustainability through the development of low-carbon technologies, resource efficiency, and new market opportunities [26, 27]. The literature emphasizes that achieving climate neutrality depends critically on sustained investment in innovation systems, particularly in research, development, and deployment of clean technologies [28], while also requiring complementary industrial and institutional policies to guide sectoral transformation and reduce transition costs [29]. Furthermore, green growth entails significant labour market adjustments, including the creation of green jobs, the

reallocation of labour across sectors, and the need for continuous reskilling to support emerging industries [21, 30]. These dynamics highlight that the success of green transition is contingent not only on environmental targets but also on the capacity of economies to manage structural change, address skills mismatches, and maintain policy credibility to sustain long-term investment and inclusive growth [28, 31]. In this context, the Green Growth perspective is particularly relevant for analysing Japan's situation, as demographic decline and labour shortages may constrain the country's ability to reallocate resources and sustain green transformation, thereby underscoring that international green cooperation must be evaluated alongside domestic economic and institutional capacity.

3.3 Migration and Labour Supply Perspective

The Migration and Labour Supply perspective explains how international labour mobility can serve as a supplementary mechanism for addressing domestic labour shortages caused by demographic decline. In the case of Japan, rapid population ageing and a shrinking workforce have increased the need for external labour inputs, leading to the introduction of policies such as the Specified Skilled Worker (SSW) scheme to expand access to foreign labour [7, 32]. Empirical evidence indicates that migration has become an increasingly important component of Japan's labour market strategy, particularly in addressing sector-specific labour shortages and sustaining economic activity under demographic pressure [32, 33]. However, the effectiveness of migration as a long-term solution remains limited. Existing studies show that Japan's migration framework continues to depend largely on temporary and segmented labour channels, which restrict opportunities for permanent settlement and fuller labour market integration [34, 35]. In addition, structural and institutional barriers, such as language requirements, workplace norms, and limited integration mechanisms, reduce the country's attractiveness to highly skilled migrants and constrain their long-term contribution to the economy [36, 37]. Consequently, although foreign workers help alleviate immediate labour shortages, migration alone cannot fully offset the effects of structural demographic decline. Accordingly, this study conceptualizes migration not as a primary solution, but as a complementary labour supply strategy whose effectiveness depends on broader institutional reforms and stronger integration capacity within the host economy.

3.4 Digitalization and Automation Perspective

The Digitalization and Automation perspective emphasizes the role of technological transformation as a partial response to labour shortages, particularly in the context of demographic decline and structural economic change. Digitalization, defined as the integration of advanced information and communication technologies into production systems, coordination processes, and organizational structures, has become a major driver of productivity and efficiency in contemporary economies [38, 39]. In sectors associated with the green transition, including sustainable manufacturing and low-carbon industries, digital technologies and automation can promote more efficient resource use, improve coordination, and strengthen production capabilities. In this way, they support economic adaptation under conditions of constrained labour supply [39]. However, the literature consistently shows that automation does not merely replace labour. Rather, it transforms the structure of work by generating new skill requirements and reshaping occupational roles [40, 41]. This suggests

that technological substitution depends fundamentally on the availability of workers with adequate technical, digital, and adaptive competencies.

In the Japanese context, where demographic ageing intensifies labour scarcity, automation is often presented as a strategic means of sustaining productivity. Nevertheless, its effectiveness remains constrained by structural and institutional factors. Existing evidence indicates that digital transformation creates new labour market challenges, including skill mismatches, uneven adaptation across sectors, and the risk of widening inequality between high-skilled and low-skilled workers [32, 42]. In addition, the benefits of digitalization do not emerge immediately, as they depend on gradual organizational adaptation, complementary investments in human capital, and supportive policy frameworks [43]. Accordingly, this study treats digitalization and automation as complementary mechanisms that can help alleviate labour shortages and improve efficiency, but not as substitutes for the skilled human capital needed to sustain the long-term green transition.

3.5 Analytical Framework of the Study

Taken together, these four perspectives form an integrated analytical framework for examining how Japan's demographic crisis affects the long-term implementation capacity of the EU-Japan Green Alliance. Human Capital Theory explains why green transition depends on the availability and reproduction of skilled labour. The Green Growth perspective provides the macro policy context by showing that low-carbon transition requires innovation, labour reallocation, and institutional capacity. The Migration and Labour Supply perspective clarifies how external labour recruitment may supplement domestic shortages, while also revealing the limitations of Japan's current migration regime. Finally, the Digitalization and Automation perspective explains how technological substitution can mitigate labour scarcity, but cannot fully replace the need for skilled workers in strategically important green sectors. In combination, these perspectives allow the study to analyse Japan's shrinking workforce not as a background demographic trend, but as a structural constraint on the implementation of bilateral green cooperation. This integrated framework also ensures that the discussion moves beyond description by linking demographic change to labour supply, technological adaptation, and the broader feasibility of green growth commitments under the Green Alliance.

4 Methods

This study adopts an explanatory qualitative case study design to examine how Japan's shrinking working-age population affects the long-term implementation capacity of the EU-Japan Green Alliance. This design was selected because the study does not seek to test causality statistically, but to explain the policy, institutional, and labour-market mechanisms through which demographic decline shapes the feasibility of bilateral green cooperation. In line with the study's two research questions, the unit of analysis is Japan's policy respone to labour-force contraction in the context of implementing Green Alliance commitments, while the case scope is limited to the interaction between Japan's demographic pressures, green transition strategies, and the implementation demands generated by EU-Japan green-growth cooperation. This is a more precise design label than the earlier generic formulation of a qualitative case study and directly addresses the reviewers' concern that the method must explain the relationship between two connected phenomena rather than merely describe them.

The study relies exclusively on secondary data, but these materials were selected through explicit inclusion criteria. Primary materials consist of official policy and institutional documents issued by the European Commission, relevant Japanese ministries and agencies, the Cabinet Office of Japan, the Immigration Services Agency, the Statistics Bureau of Japan, and international organizations such as the OECD, IEA, and UNEP. These sources were prioritized because they provide authoritative evidence on demographic trends, migration policy, labour-market conditions, and green-transition commitments. Supporting materials consist of peer-reviewed journal articles and analytically relevant reports used to interpret policy developments and situate the case within broader scholarly debates. Soure selection focused on materials that directly addressed at least one of four substantive dimensions: Japan's demographic decline, labour-market adjustment, green-growth policy, or EU-Japan green cooperation. The dataset primarily draws on contemporary materials published in the period surrounding the Green Alliance and recent demographic policy debates, while retaining earlier seminal th eoretical and background references where conceptually necessary. Sources were excluded when they were duplicative, lacked clear institutional or scholarly credibility, or discussed Japan's demographic or environmental issues without direct relevance to the study's analytical focus on implementation capacity. Data were analysed through thematic content analysis following Braun and Clarke's approach, but operationalized more explicitly for this study. First, all selected documents were read it eratively to identify recurring statements about labour decline, policy response, and green-transition implementation. Second, the material was open-coded into initial categories such as demographic pressure, green labour demand, humancapital formation, migration response, automation and digitalization, and implementation constraints. Third, these codes were grouped into broader analytical themes that corresponded directly to the study's research questions: themes related to policy responses were used to answer RQ1, while themes related to effectiveness, limitations, and implementation capacity were used to answer RQ2. Fourth, these themes were interpreted through the study's theoretical framework, in which human capital explains the need for skilled labour, migration captures external labour supply, automation captures partial labour substitution, and green growth provides the macro policy context for evaluating implementation capacity. To strengthen validity, operational triangulation was conducted by cross-checking demographic statistics with official Japanese government data, reading them alongside policy documents on green transition and labour adjustment, and then comparing both with scholarly analyses of migration, automation, and green-growth implementation. This procedure allowed the study to assess whether Japan's workforce capacity, policy responses, and Green Alliance commitments were mutually aligned or structurally mismatched.

5 Results and Discussion

5.1 Japan's demographic crisis as a structural constraint on Green Alliance implementation

Japan's demographic crisis should be understood not simply as a background socioeconomic trend, but as a structural constraint on the implementation capacity required by the EU-Japan Green Alliance. The core issue is not merely that Japan's population is shrinking, but that the country's working-age population is declining at the same time that the green transition requires a stable supply of skilled labour for renewable energy, energy efficiency, clean

manufacturing, environmental services, and low-carbon innovation. In this sense, the demographic problem directly affects the feasibility of sustaining green growth commitments, because the success of low-carbon transition depends not only on policy ambition and technological targets, but also on the human resources needed to translate these commitments into practical outcomes [8, 44]. The projected loss of approximately 20 million people in the 15 to 64 age group between 2020 and 2050 therefore has strategic implications for the Green Alliance: it narrows the labour base that supports innovation, weakens long-term implementation capacity, and increases the risk that green commitments will outpace the domestic workforce needed to realize them. This demographic constraint becomes more analytically significant when viewed through the Green Growth perspective. Green growth assumes that economic restructuring toward sustainability can be supported through technological innovation, labour reallocation, and the emergence of green sectors, yet all three processes depend on workforce readiness. In Japan's case, this means that demographic decline is not only a macroeconomic burden, but also a bottleneck in the labour-market adjustment required for decarbonization. The problem is especially acute because the sectors most relevant to green transition are also among those already experiencing labour shortages. As the earlier data in the manuscript show, manufacturing, information technology, construction, and public services are all under labour stress, indicating that the challenge is not confined to one sector but cuts across the wider productive base that supports green transformation. This finding suggests that Japan's demographic crisis is best interpreted as a structural implementation problem for the Green Alliance rather than as a separate domestic issue.

5.2 Japan's policy responses: human capital investment, migration, and automation

Japan has not remained passive in the face of this structural constraint. The evidence indicates that its policy response has developed along three interconnected lines: strengthening domestic human capital, selectively supplementing labour supply through migration, and increasing reliance on digitalization and automation. First, Japan has expanded investment in R&D, science, and technical training as a way of compensating for labour scarcity through productivity growth and innovation. Between 2013 and 2022, the number of researchers incr eased from 841,600 to 910,400, while R&D expenditure rose from ¥18.1 trillion to ¥20.7 trillion and R&D intensity increased from 3.54% to 3.65% of GDP [45]

Table 1. Trends in the Number of Researchers and Research and Development (R&D) Expenditure

Fiscal year	Number of researchers	Females (%)	R&D expenditures (billion yen)	GDP (billion yen)	Ratio of R&D expenditures to GDP (%)
2013	841,600	14.6	18,134	512,678	3.54
2014	866,900	14.7	18,971	523,423	3.62
2015	847,100	15.3	18,939	540,741	3.50
2016	853,700	15.7	18,433	544,830	3.38
2017	867,000	16.2	19,050	555,713	3.43
2018	874,800	16.6	19,526	556,571	3.51
2019	881,000	16.9	19,576	556,845	3.52
2020	890,500	17.5	19,237	539,009	3.57

2021	908,300	17.8	19,741	553,642	3.57
2022	910,400	18.3	20,704	566,490	3.65

Source: Statistics Bureau of Japan (2024) [45].

Specified Skilled Worker scheme and the gradual transition away from the older Technical Intern Training Program indicate an effort to align migration policy more closely with domestic labour shortages. At the same time, these measures remain institutionally narrow. The migration regime continues to be characterized by temporary status, restricted settlement opportunities, and limited family reunification, all of which reduce its effectiveness as a long-term solution for green-sector labour demand. Even though Japan recorded more than two million foreign workers by late 2023 and a record number of firms employing them, this increase does not automatically resolve the shortage of workers with the specific technical and adaptive skills required for the green transition. In this sense, migration helps relieve immediate labour scarcity, but it does not yet operate as a fully integrated strategy for building a stable green workforce. Third, Japan has deepened its reliance on automation, robotics, and AI as a response to shrinking labour supply. Under Society 5.0, automation is treated as a means of preserving productivity and competitiveness despite demographic contraction, and this has encouraged extensive technological investment across manufacturing, logistics, public services, and environmentally related industries. However, the evidence also shows that automation functions as a partial substitute rather than a complete solution. It can replace routine labour and improve efficiency, but it cannot eliminate the need for highly skilled workers in complex activities such as clean technology design, research coordination, system maintenance, and the localized adaptation of green infrastructure. This finding is consistent with the theoretical perspective advanced earlier: digitalization restructures tasks, but its gains remain dependent on adequate human capital and institutional adaptability.

5.3 Assessing the effectiveness of these responses for green growth

Taken together, these responses show that Japan has been moderately effective in setting the direction of green transformation, but less effective in fully securing the workforce capacity needed to sustain it. The expansion of R&D, the strengthening of technical education, the use of selective migration, and the deployment of automation all indicate policy coherence and strategic awareness. They show that Japan recognizes the labour implications of demographic decline and has moved beyond passive adjustment. In the medium term, these measures help maintain innovation capacity, support industrial upgrading, and reduce some of the most immediate risks associated with labour shortages. In this respect, Japan's response is stronger than a purely demographic reading might suggest. However, the evidence also points to clear limits. The Japanese government itself projects that by 2028 the country will require more than three million workers in digital and AI-related fields, as well as more than 2.5 million green workers to support sustainable transformation in energy and transportation. This indicates that existing policies, although directionally appropriate, are not yet sufficient to close the gap between labour demand and labour supply in emerging strategic sectors. The challenge is not simply one of labour volume, but of skill composition. Green growth requires workers who can move across new technological, environmental, and industrial domains, yet the pace of workforce adaptation appears slower than the pace of policy ambition. Migration remains too selective and restrictive to fill the gap at scale, while automation can ease routine shortages but cannot replace the complex and often placespecific skills required in renewable

energy installation, waste management, clean transport engineering, and other transition activities. Thus, Japan's strategy can be described as partially effective: it supports the trajectory of green transition, but does not yet fully guarantee the human-capital base required for long-term implementation.

5.4 Critical discussion: what this means for the Green Alliance

These findings have broader implications for how the EU-Japan Green Alliance itself should be interpreted. The current design of the alliance is strongly oriented toward technological cooperation, regulatory coordination, sustainable finance, and environmental diplomacy. Those priorities are important, but the findings of this study suggest that such a framework risks becoming overly techno-centric if it does not adequately account for differences in domestic implementation capacity. In Japan's case, the central constraint is not a lack of policy ambition, but the structural difficulty of sustaining a sufficiently large and skilled workforce under conditions of demographic decline. This means that the effectiveness of the Green Alliance cannot be assessed only in terms of shared targets, diplomatic commitment, or innovation rhetoric; it must also be evaluated in relation to labour availability, skills reproduction, and institutional adaptability within participating states. From this perspective, the Green Alliance would benefit from incorporating labour and demographic capacity as a strategic variable rather than treating it as an implicit background issue. A cooperation framework built around green growth should not assume that all partner states can implement climate commitments under similar workforce conditions. Instead, it should recognize that demographic pressures may reshape the pace, scale, and sectoral feasibility of transition policies. For Japan, this implies that bilateral green cooperation will be more sustainable if it is accompanied by stronger joint attention to workforce development, green skills, vocational partnerships, knowledge exchange, and possibly more adaptive approaches to labour mobility. The analytical implication is therefore clear: the Green Alliance should be understood not only as a legal or diplomatic framework, but as a cooperation arrangement whose long-term viability depends on whether environmental ambition is matched by adequate human and institutional capacity. That is the central contribution of the present study.

6 Conclusion

In response to RQ1, this study finds that Japan has addressed the shrinking working-age population through a threefold strategy: strengthening domestic human capital through R&D, STEM, and vocational training; supplementing labour supply through selective migration; and mitigating labour scarcity through digitalization, robotics, and automation. In response to RQ2, the study concludes that these measures have been only partially effective. They have helped Japan preserve the direction of green transformation and maintain innovation capacity, but they have not fully secured the volume and skill composition of labour required for long-term implementation of the EU-Japan Green Alliance. Theoretically, these findings suggest that Human Capital Theory remains useful for explaining the problem of skill readiness and workforce quality, but it is insufficient when used alone to interpret structural labour shortages under demographic decline. The study therefore shows the value of combining Human Capital Theory with green growth, migration, and automation perspectives in order to explain how labour capacity, policy adaptation, and technological substitution interact in shaping the

implementation of bilateral green cooperation. These findings carry several policy implications. For the Japanese government, the priority is not simply to expand employment numerically, but to strengthen greenoriented vocational education, reskilling systems, and long-term human capital formation in sectors such as renewable energy, clean manufacturing, and sustainable transport. Migration reform should also move beyond temporary labour supplementation by creating more adaptive pathways for green and digital talent. For the EU-Japan Green Alliance, the implication is equally important: cooperation frameworks should not remain overly techno-centric, but should incorporate labour and demographic capacity as strategic variables in implementation planning. This study is limited by its reliance on secondary qualitative evidence and its focus on Japan as a single case, which means it does not measure causal effects statistically or compare implementation capacity across partner countries. Future research could therefore extend this analysis through comparative studies with ageing EU member states, sector-specific studies of green workforce readiness in energy, manufacturing, and transport, and quantitative or mixed -methods designs that test the relationship between demographic decline, labour adaptation, and green transition outcomes more systematically.

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