

Institutional change and ecological structural change

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ABSTRACT

The paper presents a model discussing the political economy dimension of the green transition. There are brown sectors whose share in value-added and employment should contract and green sectors whose share should increase. Green technological changes require more skilled workers, potentially exacerbating inequalities between them and unskilled workers. Trade unions advocate for a “Just Transition”, ensuring income protection and creating new “green jobs”. However, the green restructuring of the economy demands highly subsidized investments in the short run. A political economy problem arises: how to regulate brown capitalists, support green capitalists, and prevent unskilled workers from joining forces with brown capitalists to block the green transition. The solution can be positive feedback between green technical change, non-price competitiveness, and employment. The BOPCG model allows for highlighting the role of catching up in green technologies in non-price competitiveness and endogenous institutional change to give rise to a growth path consistent with the idea of a “just green transition”.

1. Introduction

The transition towards sustainable, inclusive growth represents the critical challenge to be addressed by the international community in the coming years. On the one hand, inequality and political tensions have been growing in many developed and developing countries; in some cases, they have led to xenophobia, loss of confidence in democracy and the rise of authoritarian leaders. On the other hand, the planet's limits have been surpassed in many dimensions, from CO₂ emissions and climate change to the destruction of biodiversity. A consensus has emerged that the prevailing growth path has to be radically transformed.

However, this transformation requires implementing a broad set of policies that, in turn, are very intensive in international cooperation and domestic agreements between heterogeneous actors, whose interests are frequently in contradiction. Regarding environmental sustainability, the principle of shared but differentiated responsibilities entails that the burden of investing in environmental protection should fall mostly on the shoulders of developed countries (ECLAC, 2020). Nevertheless, suppose the developing economies are to speed up their growth rates to converge with the developed ones in terms of GDP per capita. In that case, they cannot advance in this direction on the basis of the same growth and consumption patterns of the past. It is necessary to decouple

emissions and growth, and encourage sustainable forms of consumption along with a concerted green technological endeavour geared towards sustainability. Moreover, to the extent that the environment is increasingly a matter of global concern for both producers and consumers, international competitiveness will be increasingly associated with green capabilities. The developing economies themselves have promised to reduce carbon emissions through the voluntary National Determined Contributions (NDCs) after the Paris Agreements on climate change. Regarding inclusiveness, employment depends on the growth rate of aggregate demand, which, in many developing economies, is constrained by trade imbalances, external debt and capital flights. By indicating endogenously perpetuated technological disparities, the dependency of exports on natural resources (frequently controlled by few producers, especially in the mining sector) and low wages downplay concerns about the environment and equality. Moving towards a more diversified economy and reducing the dependency on carbon-intensive exports give rise to tensions that make it difficult to sustain long-term policies and political pacts.

Post-Keynesian economics is grounded in fundamental uncertainty and adopts a class-analytic perspective, viewing income distribution as a result of power dynamics (Stockhammer, 2022). Growth models require specific institutional frameworks and social coalitions tailored to each country, supporting economic growth through a particular aggregate

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demand component (Stockhammer and Kohler, 2023). For example, an export-led model is backed by coalitions aligning sectoral and exporter interests, advocating for institutional and political reforms such as controlling wage growth and enhancing vocational training for high-skilled jobs (Baccaro and Pontusson, 2016). “Structuralist models consider the role that different institutional settings, power relations and productive structures play in shaping economic outcomes” (Porcile et al., 2023, p. 350). In particular, the authors suggest that in the BOP-constrained growth model, real exchange rate depreciation accelerates growth, enabling new technological capabilities through learning and knowledge accumulation. This technical change leads to structural change, shown by a higher income elasticity ratio of exports to imports. However, seizing this growth opportunity depends on the existing institutional framework and power relations.

In the long run, an environmentally friendly development process necessitates a policy approach prioritizing innovation in environmental technologies (Jänicke, 2008). Grin (2010) defines the sustainable transition as a “contested political process that involved the environmental movement, sustainable farmers, industrial farmers, and government agencies” (Hess, 2014, p. 2). Political power and structural change co-evolve, creating tensions influencing income distribution and industrial transformation. Progress in the just direction requires political negotiations, trial-and-error in economic policy, and coordinated deployment of industrial, technological, social, and educational policies (Porcile, 2024). Therefore, power distribution among actors is crucial in determining the outcome by influencing public policies and organizational and technological decisions (Hess, 2018). In the Post-Keynesian framework, Porcile and Sanchez-Ancochea (2021) state democracy can be ensured by strengthening social protection and technological policies to improve competitiveness. While institutional change is exogenous in the short term, it is determined by the political conflict between labor unions and capitalists in the long term. The incorporation of ecological considerations results from a political process shaped by the conflict, cooperation and recurrent negotiations (under changing power relations) among the state, private firms, and civil society groups (Shwom, 2011). These actors hold divergent interests, beliefs, and objectives, operating within asymmetrical power dynamics, which generate beneficiaries and disadvantaged groups, frequently encountering significant resistance from established entities. Examples of conflicts in socio-ecological transitions include tensions between social justice and market-oriented approaches, energy and climate justice, rapid decarbonization versus social justice, inclusive governance, and workers’ interests in carbon-intensive industries. Political ecologists have identified conflicts between environmental and labor interests, cultural and lifestyle differences, and green extractivism in the Global South. Although this aspect is widely acknowledged, the role of institutional change in the ecological transition is still poorly examined (Kalt, 2024). Therefore, the original contribution of the article is to endogenize the institutional changes related to green growth by proposing a green version of the political economy of a structuralist macroeconomic model with endogenous institutions. The latter varies driven by the conflict between green and brown political coalitions in the pursuit by the greens of a “just green transition” in developing and developed countries. Although the authors recognize that the political context is, in general, characterized by intermediate positions, the comparison between the two most extreme positions helps to highlight the underlying forces at play.

The paper presents a macroeconomic model that discusses the political economy challenges of a green transition. Section 2 briefly reviews the literature on sustainable development and social inclusion.

Section 3 presents the basic structuralist model with a green technology gap, while Section 4 discusses how different political coalitions may lead to different outcomes regarding equality and environmental sustainability. Section 5 concludes.

2. A brief review of the literature on sustainable, inclusive growth

The United Nations has identified income distribution and environmental degradation as two of the most pressing issues of the present era. This has led to increased academic interest in the relationship between socioeconomic inequalities and environmental sustainability (Chen et al., 2022): more than 68 million individuals will fall into the poverty trap by 2030 due to ecological disruption (Ehigiamusoe et al., 2022). Capitalism and colonialism have traditionally supported an institutional framework based on environmental injustice and ecological disorganization. Carrillo and Pellow (2021) argue that this framework has led to the concentration of environmental burdens on poor and marginalized communities. Torras and Boyce (1998) have found that wealthy individuals contribute more to environmental degradation due to their ownership of polluting companies and higher consumption levels. They argue that these individuals can use their political influence to exacerbate environmental problems, while the burden of environmental damage falls primarily on poorer segments of society. These findings suggest that there is a complex relationship between income distribution, environmental degradation, and social justice.

Green growth theory posits that economic expansion and environmental protection are compatible: economic growth requires technological structural change, including new products, production technologies, and improved energy efficiency, boosting ecological efficiency and leading to a more sustainable economy (Hickel and Kallis, 2020). Despite the environmental and economic benefits, the shift from brown (i.e., polluting) sectors to green (i.e., environmentally friendly) sectors could lead to an “emergency of winners and losers” reinforcing vulnerabilities and inequalities (Akinyemi et al., 2021; Sovacool et al., 2021). If its dimensions of democracy and justice are not considered, these socioeconomic inequalities could compromise social cohesion (Gatti, 2022a). While promoting low greenhouse emissions, a green growth strategy could generate income inequality and unemployment, if based only on technological progress and environmental policies (D’Alessandro et al., 2020). The working class is the most affected by green growth, as green technological changes require more skilled workers, which could exacerbate socioeconomic inequalities between less and highly-skilled workers and generate unemployment (OECD, 2023). To avoid the negative effects on employment, workers’ unions are advocating for a “Just Transition”, ensuring income protection, education, retraining, and the creation of new “green jobs” (Clarke and Sahin-Dikmen, 2020). The green transition represents an opportunity to make working-class lives better, mainly by creating new green jobs, but also by improving adaptation capacities and stopping environmental damage that affects workers in sectors only reachable through a collaboration between businesses and workers empowering marginalized groups (Clarke and Sahin-Dikmen, 2020; Velicu and Barca, 2020). However, restructuring the production system required by the green transition imposes huge investments on capitalists in the short term (Stilwell, 2021). For example, labor unions advocate an energy policy that supports clean technologies such as carbon capture systems and increasing renewable energy sources (Clarke and Sahin-Dikmen, 2020). Many of these technologies necessitate significant upfront capital investments, often accompanied by an upturn in variable production costs.

The presence of multiple parties with competing interests in resource allocation leads to conflicting societal preferences. Ultimately, the distribution of political power among these groups determines which economic institutions emerge and can be sustained over time.

Uncovering the significance of structural change factors is crucial for ensuring sustainable growth (Fabozzi et al., 2022). Democratic decision-making precludes unilateral conflict resolution, mandating collective consensus with majority support. To further their interests, individual actors must form and maintain coalitions with other stakeholders in democratic decision-making processes (Sauermaun et al., 2022). A theory of institutional change is necessary to understand economic change because institutions shape the incentives within a society, which in turn influences its structure (North, 2005). Institutional changes are driven by power relations and conflicts between opposite political coalitions, but unbalanced power relationships between coalitions could result in very fragile institutional change (Rennkamp, 2019). A political ruling class primarily composed of formal sector entities, consisting of large, capital-intensive corporations, could lack the independence necessary to form a coalition for economic growth (Grabowski, 2013).

As Ravallion et al. (2000) suggested, social inequality can potentially hinder the ability to achieve collaborative solutions to environmental issues. The latter arises from the inability of capitalism and its associated political institutions to sufficiently modernize and integrate technological solutions that harmonize ecological and economic goals. Grabowski (2013) argued that groups with diminished political influence would impede technological progress by observing that past import substitution policies by political elites in emerging nations, intended to benefit their political coalition, have created a technological backlog in agriculture. These policies extract resources from agriculture without reciprocating services, significantly reducing farmers' ability and willingness to invest in new technologies. This aspect is particularly important for developing countries, which lag behind the technological frontier, progressively advancing towards environmental innovations (ECLAC, 2020). The technological gap adversely impacts the non-price competitiveness of manufacturing firms in these economies, producing lower quality and less technologically advanced goods (Oreiro et al., 2020). Maintaining alignment with technological advancements and innovations is crucial for countries to circumvent the middle-income technology trap (Andreoni and Tregenna, 2020; Avenyo and Tregenna, 2022).

Schnaiberg and Gold (1994) assert that capitalism's competitive pressures drive businesses to expand and adopt labor-saving technologies, increasing energy and chemical use for rising profits. The state supports these activities for tax revenue and legitimacy, while workers back economic growth to replace jobs lost to technology. However, this growth leads to environmental degradation because all economic agents support the necessary economic expansion to satisfy their material needs. Favouring the creation of undemocratic institutions, Downey and Strife (2010) observe elite-controlled organizations promote capital accumulation by lowering trade barriers, expanding markets, altering property rights laws, reducing government regulations and decreasing labor costs to maintain their political power and legitimacy, but they may generate unwanted environmental degradation and inequality. However, environmental activists could change these mechanisms because the functional imperatives of capitalism do not inherently dictate them. For example, the authors highlight how the liberalized agricultural trade, promoted by elite-controlled organizations to sustain capital accumulation, has progressively compromised the ability of small farms in developing countries to survive, generating social dislocation and compromising environmental sustainability. Hess (2014) found that policy reforms supporting sustainable transitions generally occur in countries with a lower concentration of fossil fuel industries, a greater focus on green technologies, and more democratic institutions that create more political openings. In particular, the author analyses how incumbent regimes in the energy sector have effectively opposed

climate-mitigation policies in several countries, especially in the US, often due to perceived threats to profits and business models. These actors have formed alliances with conservative political parties to resist environmentally oriented policies, despite labor unions exerting effective pressure for long-term change. However, the “big green mainstream organizations” have been widely criticized for their inability to create a solid political base capable of responding to the needs of those most vulnerable social classes and ensuring an inclusive process (Ciplet and Harrison, 2020; Farrell and Stano, 2021). Therefore, the necessary condition for overcoming these conservative regimes is the creation of a solid energy-transition coalition between environmentalists, civil society actors, political parties and green industries, overcoming the possible internal tensions between social justice orientations and sustainability ones (Hess, 2014).

Focusing on the energy sector, government organizations often have distinct priorities, particularly concerning renewable energy. There is a trade-off between rapid, cost-effective project deployment and developing a national industry, which incurs additional costs, which affects policy designs and industrial outcomes, as seen in South Africa, where the National Treasury prioritizes the deployment of energy at a low cost, whereas the Department of Trade and Industry (DTI) focuses on fostering local manufacturing and job creation, resulting in a missing opportunity for the industrial sector (UN, 2023). In Mauritius, social organizations created a National Energy Audit Commission to revise energy policies, promote renewable energy, and oppose a new coal power plant in 2013. The Power Shift Campaign led to the People's Cooperative Renewable Energy Coalition, supported by the University of Mauritius, showed that transitioning to clean energy would create jobs, increase food production, diversify the economy, and stimulate research and innovation. Although the government agreed to these objectives, the political will to implement them was limited (Cantarero, 2020). Although groups solely concerned with economic growth feel no need for any change, setting as their sole objective low energy price, pro-ecology groups see the energy transition as a growth opportunity; investing in renewable energy sources opens the door to possible cross-coalition cooperation (Markard et al., 2016).

Any green development strategy must establish an eco-developmental class coalition formed by workers, entrepreneurs, and institutions (Dávila-Fernández and Sordi, 2020a; Guarini and Oreiro, 2023). Labor unions primarily focus on protecting jobs and the economic interests of workers, while mainstream environmental groups are more concerned with the conservation and preservation of nature. This class divide and differing priorities can create tensions. However, Gould et al. (2005, p. 11) argue for a possible pro-capital-green coalition between labor unions and environmental organizations, claiming a “just transition”, which is proposed as a common framework for reconciling job security with environmental sustainability, emphasizing equitable transitions for workers. Canton (2008) observes while environmentalists push for more stringent environmental regulation, expecting an increase in their profits, and polluting firms claim lower environmental regulation, eco-industries could bridge environmentalists and polluting industries, sharing common shareholders and business ventures with the latter while advocating for stricter environmental policies alongside the former. However, a coalition is possible just in case of the domestic eco-industry's dominant position in the international abatement activities market. According to Gatti (2022b), environmental regulations could represent a valuable tool to prevent environmental degradation and reduce inequalities through redistributive policies at the same time. To pursue environmental and social sustainability, political groups representing educating bourgeoisie and workers could trade less income protection in exchange for environmental protection, creating a “people's green coalition or red-green alliance”. Under their pressures, the financial elite, which invests in polluting firms, is forced to start a greening process, becoming “de facto allies”. However, the strength of this alliance depends on their effectiveness in addressing social issues. Fears of isolation could drive the working classes towards a more radical

political struggle (Gatti, 2022a). While a green-red alliance could exemplify the political alliance necessary for sustainable development by advocating for green policies and social protection, a coalition between Greens, which prioritize green capabilities over social security, and the Browns, which aim to boost competitiveness through lower wages and greener production, could promote ecological conversion by weakening social protection. Suppose industrial and technological policies enhance absorptive capabilities beyond a critical threshold. In that case, this structural change will drive dynamic exports through green innovation and non-price competitiveness, fostering economic diversification and new political interests aligned with sustainable development. As the economy diversifies, the educated bourgeoisie gains political influence, technical change creates formal jobs, and the demand for skilled labor increases. This favors worker unionization and the expansion of social protection, strengthening workers' bargaining power for social policies (Porcile, 2024). Regarding the ecological transition, an issue of political economy arises from this: how to achieve ecological structural change by building a green political coalition that can reduce the existing green technological gap and how to avoid unskilled workers aligning with brown capitalists to obstruct the shift to environmentally friendly practices.

3. The green technological gap in a structuralist model

This section introduces a green technological gap within the structuralist model developed by Porcile and Sanchez-Ancochea (2021) by describing the interactions between the green technological gap, labor market, and international competitiveness on the external market represented by the net exports. According to traditional technology gap models, disparities in long-term growth rates among countries can be analyzed by examining variations in innovation and technical advancements, which are characterized by differential rates of progress over time (Cimoli et al., 2019). The ability to keep up with green technology advancements varies significantly among countries. Environmentally friendly technologies emerge more frequently in developed nations, whereas the need for adaptation technologies is more urgent in poorer countries, which specialize in low-technology industries and primarily export raw materials. Using the country's green technology fitness, Sbardella et al. (2018) identify a direct relationship between GDP per capita and green invention capacity. While the leaders are represented by industrialized nations such as the United States, France, and Germany, the geographical distribution of green inventive activity has increasingly shifted towards Asia, whereas the representation of Latin American and African countries has remained minimal from 1980 to 2010. According to the authors, this disparity in innovative capacity is influenced by the institutional conditions that either facilitate or hinder sustainable economic growth. The extent of institutional change relies on the relative political influence held by different social groups and on societal norms concerning the minimum (for workers) and maximum (for capitalists) wage proportions and employment rates considered acceptable within a particular democratic society (Porcile and Sanchez-Ancochea, 2021). Different institutional structures can result in different technological capabilities, specialization, and growth patterns. After presenting the baseline scenario, this section evaluates how several institutional changes determined by the political conflict between different coalitions can influence the main parameters of the model and generate different growth paths.

To build the baseline structuralist model, we assume that prices, wages, and productivity remain fixed in the short run, while they fluctuate until reaching equilibrium in the labor market (indicated by a constant wage share) and the external sector (assuming no international deficit in the medium run) in the medium run. Institutions and specialization patterns remain constant in the medium run but change in the long run. We have two political coalitions that negotiate the wage share (σ) on the labor market: workers organized in trade unions and capitalists. The first coalition aims to increase their share in GDP, so they

set a wage share target (σ^D):

$$\sigma^D = \alpha_0 + \alpha_1 \varepsilon - \alpha_2 Z \quad (1)$$

The wage share depends positively on the level of employment rate (ε), positively on the institutional features that favor labor demands (captured by α_0), and negatively on the green technological gap (Z), defined as $Z = \log\left(\frac{T^F}{T}\right)$, where T^F are green technological capabilities

on the international technological frontier and T the capabilities of the country being considered. While technological asymmetries are very high between the center and periphery, it should be regarded that not all center countries are on the green international technological frontier. As a result, the level of the green technology gap still plays a role in defining competitiveness in many center countries. This means that Eq. (1) can be considered a general equation in which $Z = 0$ in the center and $Z > 0$ in the periphery or center countries that lag behind the green technological frontier.

When the economy grows and the labor market is more dynamic, the level of employment increases. Because ε represents the bargaining power of trade unions, workers are stimulated to demand a higher wage share target (Porcile and Sanchez-Ancochea, 2021), which implies the condition $\alpha_1 > 0$. Moreover, it relies on the institutional framework in which wage bargaining takes place, reflected in the parameter α_0 . We assume that a generous welfare state is more favorable to workers, attributing them higher political power, who will ask for a higher desired wage share for the same level of employment represented by a higher α_0 . A generous institutional change would involve an increase in the union's bargaining power of labor and an increase in the parameter. On the contrary, a lower α_0 indicates a more pro-capital institutional framework. When inequality is pronounced, employers possess greater power, which could result in weaker social protection programs and lower wages (Fitzgerald, 2022). Finally, the parameter α_2 translates the impact of the green technological gap on wage dynamics. A higher value of this parameter means that a rise in the green technology gap produces a stronger negative effect on real wages. Green technologies are pertinent to sustainable economic growth trajectories. Generally, highly technologically intensive industries tend to be more environmentally friendly and are likely to be associated with lower CO₂ emissions than low-tech manufacturing per unit of GDP. Consequently, industrial policies in developing countries are increasingly being restructured to promote technology-intensive machinery and the sustainable production of complex and sophisticated products (Avenyo and Tregenna, 2022). Green investments and the building of technological capabilities reduce environmental pollution as green innovations require greater technological complexity and are more knowledge-intensive than standard innovations (Barbieri et al., 2020; Horbach et al., 2013). In the same vein, De Marchi (2012) defines environmental innovations as the new technological frontier. A significant technological gap implies fewer capabilities in the periphery to expand the share of green activities. The literature shows that eco-innovations lead to an increased demand for high-skilled workers and a corresponding decrease in low-skilled employment (Fernández et al., 2024), positively affecting real wages. Therefore, if the green technological gap is high, the production structure becomes more concentrated in low-tech sectors (or brown), where the bargaining power of unions is lower than in sectors that demand more skilled workers (green).

A point to be stressed is that the assumption that the wage share responds to the employment share implies a duality in the labor market of the periphery. While informal workers have no bargaining power and indeed compromise the bargaining power of workers in the formal sector, the latter are unionized and influence the wage share as labor demand increases in the formal market. This influence can be seen as a continuum, in which the response of the wage share to employment is high in the developed economies, while it is low in the periphery due to the presence of an army of subsistence workers. In the extreme case

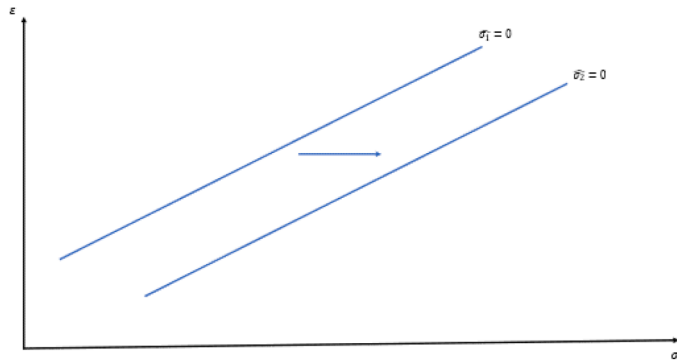


Fig. 1. The dynamic of the labor market for a reduction of the green technological gap (Z).

represented by the Prebisch-Lewis model, the wage share is not affected by the rise in labor demand in the formal sector (perfect elasticity of labor supply). However, this is, as mentioned, an extreme case: to the extent that the formal sector demands skills that subsistence workers do not command, and formal workers can more easily unionize, then it should be expected some degree of bargaining power by those workers in the formal labor market and hence an association between labor demand and wages shares.

In Fig. 1, $\hat{\sigma}_1$ represents all the positive combinations of the wage share and the employment rate that ensure the equilibrium in the labor market characterized by a positive relationship between these variables.¹ To be in equilibrium, the wage share and the desired one must be equal, which implies the following conditions:

$$\hat{\sigma} = \sigma^D - \sigma \quad (2)$$

$$\hat{\sigma} = 0 : \sigma = \alpha_0 + \alpha_1 \varepsilon - \alpha_2 Z \quad (3)$$

$$\varepsilon = \frac{\sigma}{\alpha_1} - \frac{\alpha_0}{\alpha_1} + \frac{\alpha_2}{\alpha_1} Z \quad (4)$$

Policies promoting green growth are expected to decrease the need for environmentally harmful end products and intermediary production goods, leading to a decline in labor demand within brown industries (Jackman and Moore, 2021). “This green Keynesianism aims at the creation of green and decent jobs rather than capital-intensive innovations that casualize work for millions of people” (Steviss and Felli, 2015, p. 36). Dechezleprêtre et al. (2019) identify a positive relationship between firms’ environmental and economic performance, so if green companies generate greater profits, workers’ wages in green sectors would likely surpass those in brown industries. Trade unions advocate for the just transition and sustain that creating new employment opportunities in green sectors could offer workers better working conditions, fair wages, and improved skills. Furthermore, these jobs present clear career advancements and growth paths (Healy and Barry, 2017). Consoli et al. (2016) highlight green jobs require higher non-routine cognitive abilities and interpersonal skills. If it is indeed the case that workers in green industries possess specialized skills, it is plausible to observe higher wages in green sectors (Jackman and Moore, 2021). However, reallocation costs are proportional to the disparity in skill sets between “origin” and “destination” occupations. Consequently, the job creation effect of the green stimulus is positively correlated with the proportion of workers possessing the skills most essential for green activities (Vona, 2023, 2021). However, in emerging economies, skilled labor is a scarce factor (Menéndez González et al., 2023). Therefore, despite the positive

impacts mentioned above, greening the economy could reduce employment because job losses will occur in carbon-intensive sectors, which may contract or grow slowly, while new jobs will emerge in low-carbon, generally more labor-intensive sectors. Moreover, net job creation is expected to decline as low-carbon technologies mature. Structural unemployment may result from labor immobility and skills gaps in emerging sectors (Martínez-Fernández et al., 2010).

Therefore, if the green technological gap is reduced, the expansion of green sectors will require more skilled workers who will demand a higher real wage in the domestic labor market. Moreover, democracy is expected to produce more pro-labor institutional change and increase wages (Tan, 2011). Therefore, the shifts to the right of the curve $\hat{\sigma} = 0$ are caused by a more generous welfare change ($\uparrow \alpha_0$) or a reduction in the green technological gap ($\downarrow Z$), but the joint effect could determine a more significant curve shift to the right.

The BOPCG model assumes that exports should grow at the same rate as imports to prevent external debt from entering into an explosive path. The growth of exports relative to that of imports depends on price and non-price competitiveness. Price competitiveness, in turn, depends on the wage share, which defines unit labor costs. Non-price competitiveness depends on relative technological capabilities, captured by the green technological gap. The increase in imports is a function of both price and non-price competitiveness and of the level of employment, captured by ε (the higher the level of employment, the higher domestic aggregate demand, the higher are imports, ceteris paribus). There is also a direct association between economic and employment growth, assuming a constant rate of productivity growth. As a result, it is possible to write the BOPC growth as a function of price, non-price competitiveness and the level of employment, as in Eq. (5):

$$\hat{\varepsilon} = \beta_0 - \beta_1 \sigma - \beta_2 \varepsilon - \beta_3 Z, \quad (5)$$

all parameters positive.

AA positive institutional change that favours the improvement of the country’s technological capabilities and the specialization of production (a rise in β_0) would cause a shift to the right of the curve $\hat{\varepsilon} = 0$. Higher environmental efficiency (lower Z) is expected to be linked to enhanced non-price competitiveness, resulting in increased exports, employment rate, and output growth rate (Dávila-Fernández et al., 2023). Introducing the green technological gap in the equations, we assume that green technologies influence the growth rate of the net export, competitiveness, and, consequently, the economy’s growth rate (Guarini and Porcile, 2016). In sum, β_3 represents the impact of ecological structural change on international competitiveness.

With prices defined as a constant markup over labor costs, the parameter σ can be seen as a proxy for the real exchange rate. In this respect, the model differs from the canonical BOPCG models, which do not include the real exchange rate among the determinants of the long-run growth rate. However, taking into account this variable is in line

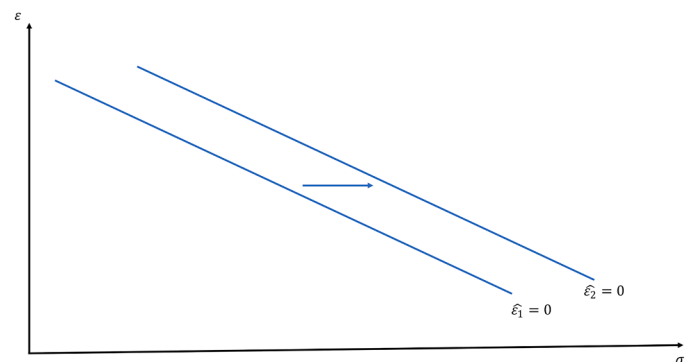


Fig. 2. Equilibrium in the external market and the reduction of the green technological gap.

¹ When the level of employment is high, the bargaining power of workers increases; so, they could demand higher wages related to the labor productivity (Cafferata et al., 2021).

with the empirical literature that suggests that the real exchange rate matters for growth (Missio et al., 2015) and other theoretical developments that include the real exchange rate among the determinants of structural transformation (Blecker, 2022).

As shown in Fig. 2, the equilibrium in the external market is represented by the curve $\hat{\varepsilon}_1 = 0$, which implies:

$$\hat{\varepsilon} = 0 : \varepsilon = \frac{\beta_0 - \beta_1\sigma - \beta_3Z}{\beta_2} \quad (6)$$

Its downward sloping can be explained by the fact that when the wage share increases, the real exchange rate decreases, generating a deficit in the current account and compromising international competitiveness, given the nominal exchange rate. The current employment level is incompatible with the equilibrium in the external market, which imposes zero deficit² in the current account. To reduce the deficit and improve competitiveness, it is necessary to reduce imports by reducing the employment rate because there will be just one value of the employment rate that returns zero net exports for each value of the wage share (Porcile and Sanchez-Ancochea, 2021).

According to Spinola (2020), countries specializing in producing and exporting low-tech raw materials tend to fall progressively behind those focusing on producing and exporting high-tech manufactured goods; productivity and real wages exhibit parallel growth patterns influenced by technological progress. Reducing the green technological gap, a positive technological change determines an increase in diversification and relative wages, generating a shift of the curve to the right in $\hat{\varepsilon}_2 = 0$ (Cimoli et al., 2019). Policies targeting industrial and technological development to narrow the technology gap and promote structural change lead to an increase in the relative growth rate and relative wages. The response on the supply side is not dependent on price flexibility or rapid reallocation of production factors, but instead on learning and innovation systems that emerge from the interaction between institutions, policies, and the production structure (Cimoli and Porcile, 2014). Whether the green technological gap decreases, the employment rate increases because an international competitive advantage is created by moving closer to the green frontier and employing high-quality skills of the labor force. Higher green technologies sustain a higher employment rate or the real exchange rate for the same level. The green technology gap affects competitiveness because products derived from environmental innovations exhibit superior quality, thereby linking an increase in green efficiency to higher export levels.

Once the characteristics of each market have been defined, we can identify the solution of the dynamic system which guarantees the

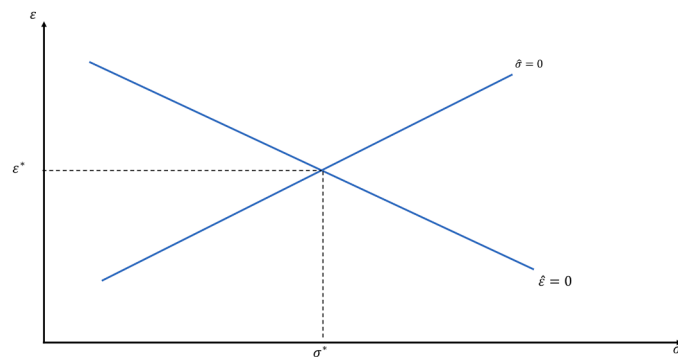


Fig. 3. The medium-term equilibrium.

² In the short term, international lending can offset temporary fluctuations in exports and imports. However, the model posits that, in the medium term, the current account deficit per unit of capital must be zero.

simultaneous equilibrium on the domestic and external sectors (see Fig. 3), whose stability analysis is contained in Appendix A:

$$\begin{cases} \hat{\sigma} = 0 \\ \hat{\varepsilon} = 0 \end{cases} \begin{cases} \alpha_0 + \alpha_1\varepsilon - \alpha_2Z - \sigma = 0 \\ \beta_0 - \beta_1\sigma - \beta_2\varepsilon - \beta_3Z = 0 \end{cases} \begin{cases} \sigma^* = \frac{\alpha_0\beta_2 + \alpha_1\beta_0 - Z(\alpha_1\beta_3 + \alpha_2\beta_2)}{\beta_2 + \alpha_1\beta_1} \\ \varepsilon^* = \frac{\beta_0 - \alpha_0\beta_1 + Z(\alpha_2\beta_1 - \beta_3)}{\beta_2 + \alpha_1\beta_1} \end{cases}$$

The impact of a reduction of the green technological gap on the equilibrium of the dynamic system is formally given by:

$$\frac{\partial \sigma^*}{\partial Z} = \frac{-\alpha_1\beta_3 - \alpha_2\beta_2}{\beta_2 + \alpha_1\beta_1} < 0 \quad (7)$$

$$\frac{\partial \varepsilon^*}{\partial Z} = \frac{\alpha_2\beta_1 - \beta_3}{\beta_2 + \alpha_1\beta_1} \rightarrow \frac{\alpha_2\beta_1 - \beta_3}{\beta_2 + \alpha_1\beta_1} < 0 \text{ if } \beta_3 > \alpha_2\beta_1 \quad (8)$$

The reduction of the green technological gap will certainly increase the wage share, while it will positively influence the employment rate only with a strong positive impact of “ecological structural change on international competitiveness”, expressed by the parameter β_3 (see Fig. 4). The improvement of the green technological capabilities of the country generates an increase in the wage share increases, so the isocline $\hat{\sigma} = 0$ shift to the right. The isocline $\hat{\varepsilon} = 0$ shifts to the right, but the employment rate increases only if the effect of the reduction of Z on ε is greater than the effect on σ . In point B, the employment rate is lower than the previous equilibrium point, while in point C, it is equal to that in point A; beyond this, the employment rate increases following a reduction in Z (for example, in point D). Green technological change can represent an essential driver of international competitiveness: green innovation can improve price competitiveness, reducing production costs, but also non-price competitiveness increasing the environmental performance and quality of products perceived by the international markets (Guarini and Oreiro, 2023). Non-price or technological competitiveness plays a more significant role in determining the export performance of high-tech products, such as environmentally friendly ones, whereas price competitiveness is the primary factor influencing the exports of low-tech products (Bottega and Romero, 2021). However, the relationship between income distribution and the green technological gap can be characterized as nonlinear and inverse-U-shaped (Blecker, 2022): when the wage share is initially low, an increase in the wage share results in greater innovation. This is because firms respond to higher labor costs and improve relative technological capabilities. However, when the wage share is already high, firms lack the motivation and resources to innovate further. As a result, the technological level declines. Overall, the reduction of the distance of the country from the international green technological frontier could potentially lead to higher employment and improved income distribution if its effect on the non-price competitiveness is higher than its impact on the price competitiveness.

The ninth Sustainable Development Goal of the United Nations en-

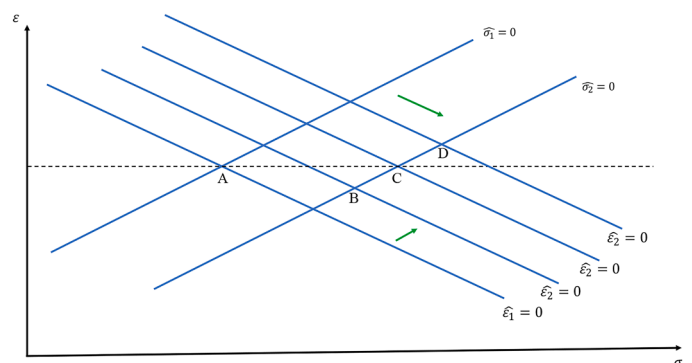


Fig. 4. The green technological gap reduction and the new equilibrium.

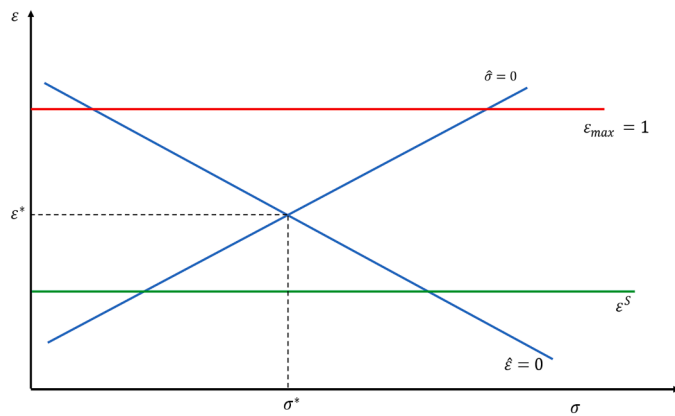


Fig. 5. The sustainable employment rate.

courages the States to start inclusive and sustainable industrialization, aiming to increase the industrial share of employment and gross domestic product by 2030. A green investment policy can successfully redirect production towards high-tech industries and services with low emissions, decreasing domestic emissions even as GDP grows (Althouse et al., 2020). Green industrial policies present significant opportunities for emerging and low-income countries to achieve sustainable industrialization, fostering job creation and economic prosperity (Avenyo and Tregenna, 2022). In particular, a short-run sustainable strategy entails improving the environmental efficiency of production systems via ecological macroeconomic policies, which aim to reduce CO₂ emissions, decrease fossil fuel dependence, enhance industrial competitiveness, lower energy costs, and boost productivity and economic growth, thereby fostering environmental sustainability (Wenlong et al., 2023). For example, Irfan et al. (2021) observed how an increase in renewable energy and energy efficiency has effectively reduced the environmental intensity in Nepal and India in the short term. Ghana's low-carbon development planning can enhance energy efficiency, reduce emissions, and attract international climate support, providing significant economic and developmental co-benefits (van Tilburg et al., 2011). UN (2023) reported that the 2014 Renewable Energy Law incentivized the private sector to increase electricity production from renewable sources in Egypt. Similarly, in the Philippines, the Renewable Energy Act of 2008 offered incentives to promote the adoption of new technologies. Reducing the green technological gap positively affects wage share and employment rate in the domestic labor market so that the economy can reach a sustainable employment rate (see Fig. 5). In particular, Stern and Zenghelis (2020) emphasize how sustainable investments, such as clean energy infrastructure, are projected to enhance short-term employment, lower energy costs, and yield economies of scale and productivity gains over the long term (Malliet et al., 2020). Assuming that the labor force corresponding to the population is equal to 1, we start with the total output of the country:

$$Y = \varepsilon \pi \quad (9)$$

Where Y is the GDP, ε employment rate, π labor productivity. Promoted by green technological change, relocating resources from conventional innovations to environmental innovations increases environmental efficiency (Guarini and Porcile, 2016). With a growing stock of green technologies, greenhouse gas emissions decrease, mitigating socioeconomic and environmental well-being risks caused by

continued economic growth (Althouse et al., 2020). To analyze the relationship between economic growth and environmental pressure, we introduce the greenhouse gas emissions level to define a "green" target:

$$H = Y\gamma \quad (10)$$

Where H is the amount of pollution, Y is the GDP, and $\gamma = H/Y$ is the pollution intensity that identifies the stock of emissions per output unit. Combining Eqs. (9) and (10), we obtain the employment rate:

$$\varepsilon = H/\pi\gamma \quad (11)$$

The process of ecological transition has been observed to spontaneously occur within dynamic growth models, where political coalitions play a significant role in shaping the "rules of the game" and establishing policy incentives that can potentially facilitate both social equality and ecological transition (Gatti, 2022b). "In the case of technology transitions to low-carbon sources of energy, there is growing evidence that even in countries with a strong political consensus in favor of a transition, the pace has been slow in comparison with the need to reduce greenhouse gases. One factor that affects the slowness of the transition is political resistance from the incumbent industrial regime" (Hess, 2014, p. 1). Countries with more generous welfare regimes where more political power is concentrated in the hands of green coalitions tend to support proactive climate policies. While the brown coalition has no interest in reducing the level of pollution, the green coalition promotes a sustainable target for the pollution level (H^S). Given π and γ , we can obtain the corresponding sustainable employment rate:

$$\varepsilon^S = H^S/\pi\gamma \quad (12)$$

Following the Schumpeterian studies regarding the progression of the technology gap, a greater green technology gap (Z) corresponds to an increased potential for the transmission of green technological advancements from the center to the periphery. Given the center countries' value of environmental efficiency, the pollution intensity can be expressed as a function of the green technological gap as follows:

$$\gamma = f(Z), \quad f'(Z) > 0 \quad (13)$$

A reduction of the green technological gap (Z) can lead to an improvement in environmental efficiency, decreasing γ , and an increase in the sustainable employment rate ε^S . To promote inclusive and sustainable development, the green coalition must reduce the sustainable pollution target and simultaneously decrease pollution intensity and, in turn, the green technological gap by stimulating environmental innovations. On the contrary, the political power of the brown coalition is interested in maintaining high pollution levels and curbing the rise in the sustainable environmental frontier, pushing the economy towards low-tech sectors where the least skilled workers and lowest wages are concentrated and are more price competitive. This means that to understand the drivers of the ecological transition, examining its technological dimension in isolation is not enough, but it is necessary to make explicit its political dimension. To this end, the next section will illustrate how the political conflict between the green and brown coalitions can condition ecological transition.

4. Political coalitions and political equilibrium

As discussed in the literature review, the critical challenge for having ecological structural change is building a strategic coalition that reduces the green technology gap and accelerates the diffusion of green

technology. We express this challenge in terms of building institutions for learning that reduce the green technology gap in the long-run equilibrium. We will assume, already highlighted in the previous sections, that the green sector is more intensive in technology and skilled labor, which form the basis of the green coalition. The latter would focus on reducing the green technology gap, and, hence, on institutions that accelerate green technical change to increase non-price competitiveness; the brown coalition would support curbing social protection to reduce the wage share and increase price competitiveness. As the name suggests, a green coalition should embrace a set of political and social forces beyond the political parties concerned exclusively with environmental issues. It reflects the growing concern in parts of civil society and political parties about the need to take the environment seriously and to place its protection in a key position within the political agendas and social demands. In this section, we focus on green versus brown. Still, in the next section, we further differentiate the set of interests in political action by making a distinction between green (prioritize the environment), pro-labor (prioritize the wage share and labor rights), pro-capital (prioritize pro-capital and pro-market policies) and brown (prioritize the old industrial basis which is carbon intensive).

4.1. A simple model of political economy and green technological catching up

In this section, we discuss the forces governing the evolution of the green technology gap (Z) in the long run. This evolution will depend on technological factors shaping the international diffusion of green technology and political forces shaping institutions that boost or hamper this diffusion. In the strong version of their hypothesis, [Porter and Van der Linde \(1995\)](#) affirm that environmental regulation can increase firm competitiveness, encouraging the adoption of environmental innovations. The effectiveness of industrial or environmental policies is closely intertwined with the political economy of countries and the relative influence of various stakeholders. This influence and power structure will affect the direction of technical change towards price or non-price competitiveness.

We will make some assumptions about the political economy of structural and institutional changes. We define G as the political bargaining power of skilled workers and green capitalists, which we assume falls with the rise in the green technology gap. We assume that the political power of the green coalition is lower when the green technology gap is higher because its weight and influence on the economic structure and performance are lower. A higher green technology gap implies that most employment and exports are in the hands of brown capitalists who hire unskilled workers, who will have the upper hand in the power conflict. Besides the green technology gap, other forces shape the bargaining power of the green coalition in the realm of political competition. In some cases, political success breeds more political success; the coalition that gains power uses it successfully to expand its political clout further, and there are increasing returns to the accumulation of power. In other cases, decreasing returns set in as compensating forces gradually emerge in society to prevent the green or brown coalitions from monopolizing political power. We will focus on the second scenario.

Regarding technological change, we will assume a linear catching-up model for the green technology gap (Z) that allows for higher technological spillovers when the green technological gap is higher. It is important to mention that Verspagen and other authors used a nonlinear specification for the catching-up function. However, as we have included several variables and dimensions in the model, making it fairly

complex, we decided to use the linear specification to highlight the political dimensions of the outcomes. Please note that the Verspagen's specification gives two equilibria, but only one of them is stable. Hence, the economy would either tend to behave explosively (assuming it could not remain for a long time in the unstable equilibrium) or transit to the stable equilibrium. By using the linear specification, we focus on the stable equilibrium and exclude the explosive trajectory.

We also assume that if the green coalition is strong, then the institutions for learning in the periphery will be more developed, and so will the regulatory framework encouraging the diffusion of green technology. We capture the regulatory framework with the variable G : a higher G means more efforts at green technological catching up. As a result, the flow of technology towards the periphery will increase with G .

The rate of change ($z = \frac{\dot{Z}}{Z}$) of the green technology gap Z is formalized as follows:

$$z = h_0 - h_g G - h_z Z \quad (14)$$

The evolution of the technological gap is captured in [Eq. \(14\)](#): h_0 gives the rate of growth of autonomous innovation in the center as compared to the periphery or the velocity at which the international technological frontier progresses due to innovations originating in the North³; h_z is the rate at which the periphery learns from the center out of technological spillovers (the effectiveness of the domestic policy to transform potential spillovers into effective spillovers). A country that experiences a technological gap has the potential to accelerate its economic growth by engaging in imitation or “catching-up” strategies ([Fagerberg and Verspagen, 2002](#)).

The technological gap model is based on the role of knowledge spillovers that flow toward laggard economies. It is assumed that its innovative activity is the sole contributor to the growth of the knowledge stock in the leading country. On the other hand, the laggard countries can leverage the higher level of knowledge developed by the leader to accelerate their technical change through imitation and catch-up processes ([Castellacci, 2002](#)). Over time, technological knowledge spreads to other firms and nations. In equilibrium, the flow of innovations in the center and the diffusion rate in the periphery are equal, and the technological gap is stable.

While innovation in the center can create divergence among firms or nations, imitation tends to diminish disparities in technological capabilities and consequently promote convergence ([Fagerberg and Verspagen, 2002](#)). As mentioned, we assume in [Eq. \(14\)](#) that potential spillovers increase as a linear function of the technology gap (Z in our notation), suggesting that the greater the technological distance, the greater the potential for the follower country to catch up. “If the North adopts an industrial policy that promotes learning, and the South does not respond quickly, the technology gap will widen and the South will fall behind. In general, the evolution of the technological gap, competitiveness, and growth depends on the relative speed of innovation in the North and the diffusion of technology to the South” ([Cimoli et al., 2019](#)).

In turn, h_g gives the impact of existing regulations on environmental standards on the diffusion rate of green technologies. In some cases, those regulations are encouraged by the international cooperation of labor unions, as the “...technological transfer from the North to the South is a demand coming from unions of the Global South that now forms part of the climate change policies of the International Trade Union Confederation” ([Räthzel and Uzzell, 2011](#), p. 1219). If the center adopts an environmental policy that includes green economic restructuring in the periphery, it will not use its technological capabilities “to maximize advantages in trade, but to encourage international technological diffusion”

³ Green innovation in the North may be encouraged by more stringent international green standards.

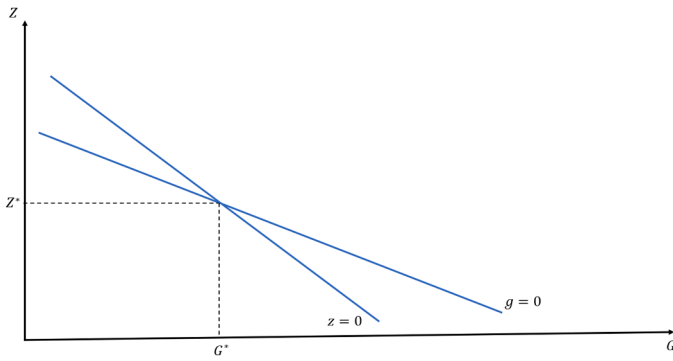


Fig. 6. Phase diagram of the political economy dynamics.

(Althouse et al., 2020, p. 9). In addition, the periphery should invest in building the institutions required for technological learning. The environmental efficiency of the periphery is not the outcome of automatic technological spillovers, but it stems from social capabilities and, in particular, green *absorption capabilities*, captured by G . The higher is G , the stronger the institutions for learning in the periphery, the higher will be the green absorptive capabilities, and the higher the rate of learning from the technological stock of the center.

The growth rate of the political power of the green coalition g falls with the technology gap. It declines with the political power it has already acquired, assuming a scenario of decreasing returns of power accumulation. These assumptions and behavioural rules can be formalized as follows:

$$g = j_0 - j_g G - j_z Z \quad (15)$$

Environment protection is central in ongoing discussions concerning the international political economy, which requires international cooperation (Galindo et al., 2020). Partnerships are essential, and the 17th Sustainable Development Goal aims to rejuvenate the worldwide alliance among governments, the private sector, and civil society to guarantee that everyone is included and supported. This goal encompasses various objectives, such as strengthening the global partnership for sustainable development by mobilizing and exchanging knowledge, expertise, technology, and financial resources. In sum, international environmental agreements and cooperation can promote environmental awareness, favoring the emergence of green movements or coalitions.

Existing institutions impact the bargaining power and composition of the group's interests (Dávila-Fernández and Sordi, 2020b). For example, the ambitious supranational environmental goals for 2030 and 2050 set by the European Green Deal strategy can significantly influence the national green political debate. Stringer environmental international agreements, standards, or institutions may positively affect the political power of the green coalition, and these exogenous factors are represented in Eq. (15) by the parameter j_0 . Institutional changes required to attain social and environmental sustainability pose significant challenges. Efforts to enhance fundamental social safeguards encounter substantial political resistance, not to mention the opposition faced by policies that could substantially decrease corporate profits, such as the liberation of patents for global knowledge exchange (Althouse et al., 2020). In the periphery, specialization in commodities favors brown coalitions that may wield considerable economic power, keeping the economy tied to the low-tech sectors, represented by the parameter j_z , which make difficult to dislodge their consequent political power, particularly in peripheral regions, or it may in any case represent a significant obstacle to the formation of a strong green coalition.

The parameter j_g expresses the political power already acquired by

the Green coalition. The work by Dávila-Fernández and Sordi (2020a) points out that the absence of a social consensus on the environmental challenge makes it more difficult to adopt green policies. However, as the green political coalition gains political power and strengthens institutions for green innovations, social perceptions change and become more favorable to those policies, reinforcing the influence of this coalition. At the same time, firms would increase their environmental awareness to respond to increasing international demand for greener goods and services (Chiou et al., 2011). As attitudes toward climate policies become more favorable, policymakers can introduce stricter environmental regulations (Cafferata et al., 2021). Similarly to Sordi and Dávila-Fernández (2023), we can suppose that increasing awareness of the need to start the ecological transition could increase green technological investments, stimulating the green individual attitudes and the bargaining power of the green coalitions. As a result, the parameter j_g embeds the net effect of two different institutional parameters: one which captures political barriers to the accumulation of power ($j_{g1} < 0$) and one which captures social conventions in favor of sustainability ($j_{g2} > 0$). The net effect of these opposite forces would probably be negative⁴ ($j_{g1} > j_{g2}$): green attitudes mitigate political barriers but not overcome them.

The two isoclines and equilibrium values of the system are the following:

$$\begin{cases} z = 0 \\ g = 0 \end{cases} \Rightarrow \begin{cases} h_0 - h_g G - h_z Z = 0 \\ j_0 - j_g G - j_z Z = 0 \end{cases} \Rightarrow \begin{cases} Z^* = \frac{j_0 h_g - h_0 j_g}{h_g j_z - h_z j_g} \\ G^* = \frac{j_z h_0 - h_z j_0}{h_g j_z - h_z j_g} \end{cases}; \begin{cases} \frac{h_0}{h_z} - \frac{h_g}{j_z} G = Z \\ \frac{j_0}{j_z} - \frac{j_g}{j_z} G = Z \end{cases}$$

To analyze its stability, we estimate the Jacobian of the dynamic system formed by Eqs. (14) and (15):

$$J = \begin{bmatrix} -h_z & -h_g \\ -j_z & -j_g \end{bmatrix}$$

The two conditions of stability are:

- I. $T|J| < 0 : -h_z - j_g < 0$
- II. $Det|J| > 0 : h_z j_g - j_z h_g > 0 \rightarrow j_z h_g - h_z j_g < 0 \rightarrow \frac{h_z}{h_g} > \frac{j_z}{j_g}$

To examine the impact of the political conflict in support of the green coalition and the reduction of the green technological gap, we estimate the partial derivatives in the equilibrium point. The stability conditions show that Z^* and G^* denominators are negative. For construction, also $(j_0 h_g - h_0 j_g)$ and $(j_z h_0 - h_z j_0)$ must be negative to have Z and G positive. As a result, there is no ambiguity in the sign of the derivatives estimated below:

$$\frac{\partial Z^*}{\partial h_0} = -\frac{j_g}{h_g j_z - h_z j_g} > 0 \quad \frac{\partial G^*}{\partial h_0} = \frac{j_z}{h_g j_z - h_z j_g} < 0 \quad (16)$$

⁴ The importance of political dynamics in defining the equilibrium solution of the model must be stressed. If green attitudes grow excessively through self-reinforcing mechanisms overcoming political barriers ($j_{g2} > j_{g1}$), we could suppose increasing returns in the green coalition dynamic (North, 1990, 1991; Méndez et al., 2019), namely, “+ $j_g G$ ”. This assumption could reflect some interesting contributions about green attitudes. Given the stability conditions, if there are increasing returns to power accumulation the model becomes unstable (when $+j_g > 0$ we have a saddle path equilibrium). In this case, some exogenous stabilizing force will be crucial for preventing an economy from moving towards a “pure” brown economy if the initial position of this economy is one in which the brown coalition is stronger than the green. For instance, international agreements on green standards and a global carbon price would be instrumental in avoiding a corner solution in which the green coalition is powerless.

$$\frac{\partial Z^*}{\partial j_z} = -\frac{h_g(h_g j_0 - h_0 j_g)}{(h_g j_z - h_z j_g)^2} > 0 \quad \frac{\partial G^*}{\partial j_z} = -\frac{h_z(h_g j_0 - h_0 j_g)}{(h_g j_z - h_z j_g)^2} < 0 \quad h_g j_0 - h_0 j_g < 0 \rightarrow \frac{h_g}{h_0} > \frac{j_g}{j_0} \quad (17)$$

$$\frac{\partial Z^*}{\partial j_g} = -\frac{h_g(h_0 j_z - j_0 h_z)}{(h_g j_z - h_z j_g)^2} > 0 \quad \frac{\partial G^*}{\partial j_g} = -\frac{h_z(h_0 j_z - j_0 h_z)}{(h_g j_z - h_z j_g)^2} < 0 \quad h_0 j_z - j_0 h_z < 0 \rightarrow \frac{h_0}{h_z} > \frac{j_0}{j_z} \quad (18)$$

Fig. 6 shows the phase diagram of the system of differential Eqs. (14) and (15) in this scenario. Their equilibrium solution will feature a lower Z and a higher G when: (i) the velocity with which the technological frontier moved concerning the periphery is lower (low h_0), (ii) when the brown coalition has less capacity to translate its economic power⁵ into political power (low j_z), and (iii) when the green coalition succeeds in preventing the countervailing forces of the brown coalition from checking the green hegemony (low j_g).

4.2. The impact of institutional and ecological transition in the labor market

The long-run equilibrium value of Z^* can be used to examine the effects of different political coalitions on wages and employment. To investigate these effects, we replace Z by Z^* in the short-run equilibrium values:

$$\begin{cases} \hat{\sigma} = 0 \\ \hat{\varepsilon} = 0 \end{cases} \begin{cases} \alpha_0 + \alpha_1 \varepsilon - \alpha_2 Z - \sigma = 0 \\ \beta_0 - \beta_1 \sigma - \beta_2 \varepsilon - \beta_3 Z = 0 \end{cases} \begin{cases} \sigma^* = \frac{\alpha_0 \beta_2 + \alpha_1 \beta_0 - Z(\alpha_1 \beta_3 + \alpha_2 \beta_2)}{\beta_2 + \alpha_1 \beta_1} \\ \varepsilon^* = \frac{\beta_0 - \alpha_0 \beta_1 + Z(\alpha_2 \beta_1 - \beta_3)}{\beta_2 + \alpha_1 \beta_1} \end{cases}$$

$$\begin{cases} \sigma^{**} = \frac{\alpha_0 \beta_2 h_g j_z - \alpha_0 \beta_2 h_z j_g + \alpha_1 \beta_0 h_g j_z - \alpha_1 \beta_0 h_z j_g - \alpha_1 \beta_3 h_g j_0 + \alpha_1 \beta_3 h_0 j_g - \alpha_2 \beta_2 h_g j_0 + \alpha_2 \beta_2 h_0 j_g}{\beta_2 h_g j_z - \beta_2 h_z j_g + \alpha_1 \beta_1 h_g j_z - \alpha_1 \beta_1 h_z j_g} \\ \varepsilon^{**} = \frac{\beta_0 h_g j_z - \alpha_0 \beta_1 h_g j_z - \beta_0 h_z j_g + \alpha_0 \beta_1 h_z j_g + \alpha_2 \beta_1 h_g j_0 - \alpha_2 \beta_1 h_0 j_g - \beta_3 h_g j_0 + \beta_3 h_0 j_g}{\beta_2 h_g j_z - \beta_2 h_z j_g + \alpha_1 \beta_1 h_g j_z - \alpha_1 \beta_1 h_z j_g} \end{cases}$$

$$Z^* = \frac{j_0 h_g - h_0 j_g}{h_g j_z - h_z j_g} \quad (19)$$

This substitution gives us the long-term equilibrium values of σ and ε , namely σ^{**} and ε^{**} :

⁵ Drawing attention to the energy sector, Newell (2019) emphasizes a fundamental conflict around the perceived necessity for transformation between established industry players and emerging technology providers and financiers who aim to establish a larger market share for low-emission alternatives. The “animal spirit” of capitalism is a driving force behind this transition process, as it relentlessly pursues profits through innovation and disruptive practices. The outcome of this process depends on various factors, including economic and political power of incumbent regime, as well as its willingness to participate in the transition process. However, the latter is influenced by the close associations with existing incumbent economic interests, which may be threatened by interventions that disrupt their control over production, technology, and finance.

$$\begin{cases} \sigma^{**} = \frac{\alpha_0 \beta_2 + \alpha_1 \beta_0 - \left[\frac{j_0 h_g - h_0 j_g}{h_g j_z - h_z j_g} \right] (\alpha_1 \beta_3 + \alpha_2 \beta_2)}{\beta_2 + \alpha_1 \beta_1} \\ \varepsilon^{**} = \frac{\beta_0 - \alpha_0 \beta_1 + \left[\frac{j_0 h_g - h_0 j_g}{h_g j_z - h_z j_g} \right] (\alpha_2 \beta_1 - \beta_3)}{\beta_2 + \alpha_1 \beta_1} \end{cases}$$

Considering the various parameters of the model, the potential set of political coalitions is greatly expanded. Besides green and brown, we may have pure pro-labor coalitions led by the unions and driven by the objective of building a welfare state and strengthening the bargaining power of labor; and pure pro-capital coalitions (against social legislation) whose aims are to reduce the wage share and increase price competitiveness across the board, led by the representatives of the prominent capitalists' groups. We can compare the outcomes in terms of employment and wage share associated with the policies defended by the pro-labor coalition ($\uparrow \alpha_0$), the pro-labor coalition ($\downarrow \alpha_0$), the green coalition ($\uparrow j_0, \uparrow j_g, \downarrow j_z$) and the brown coalition ($\downarrow j_0, \downarrow j_g, \uparrow j_z$). We may also consider different political combinations of these coalitions to form broader coalitions that would be more powerful and carry more influence on policy-making. To this end, we examine the significant derivatives:

The stability conditions from the previous systems are:

1. $\beta_2 + \alpha_1 \beta_1 > 0$
2. $h_g j_z - h_z j_g < 0; h_g j_0 - h_0 j_g < 0; h_0 j_z - j_0 h_z < 0$

The signs of derivatives are:

$$\frac{\partial \sigma^{**}}{\partial \alpha_0} = \frac{\beta_2}{\beta_2 + \alpha_1 \beta_1} > 0 \quad \frac{\partial \varepsilon^{**}}{\partial \alpha_0} = -\frac{\beta_1}{\beta_2 + \alpha_1 \beta_1} < 0 \quad (20)$$

Table 1

Possible outcomes in terms of wage share and employment level of several coalitions.

	PRO-LABOR ($\uparrow \alpha_0$)	PRO-CAPITAL ($\downarrow \alpha_0$)
GREEN ($\uparrow j_0, \downarrow j_g, \downarrow j_z$)	$\uparrow \sigma; \uparrow \varepsilon$ (only if $\beta_3 > \alpha_2 \beta_1$)	$\downarrow \sigma; \uparrow \varepsilon$ (only if $\beta_3 > \alpha_2 \beta_1$)
BROWN ($\downarrow j_0, \uparrow j_g, \uparrow j_z$)	$\downarrow \sigma; \uparrow \varepsilon$	$\downarrow \sigma; \uparrow \varepsilon$

$$\frac{\partial \sigma^{**}}{\partial j_0} = \frac{h_g(\alpha_1\beta_3 + \alpha_2\beta_2)}{(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)} > 0 \quad \frac{\partial \varepsilon^{**}}{\partial j_0} = \frac{h_g(\alpha_2\beta_1 - \beta_3)}{(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)} > 0 \text{ if } \alpha_2\beta_1 - \beta_3 < 0 \quad (21)$$

$$\frac{\partial \sigma^{**}}{\partial j_g} = \frac{h_g(h_0 j_z - h_z j_0)(\alpha_1\beta_2\beta_3 + \alpha_2\beta_2^2 + \alpha_1^2\beta_1\beta_3 + \alpha_1\alpha_2\beta_1\beta_2)}{[(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)]^2} < 0 \quad (22)$$

$$\frac{\partial \varepsilon^{**}}{\partial j_g} = \frac{h_g(h_0 j_z - h_z j_0)(\alpha_2\beta_1\beta_2 - \beta_2\beta_3 + \alpha_2\beta_2^2 + \alpha_1\alpha_2\beta_1^2 - \alpha_1\beta_1\beta_3)}{[(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)]^2} > 0 \quad (23)$$

$$\frac{\partial \sigma^{**}}{\partial j_z} = \frac{h_g(h_g j_0 - h_0 j_g)(\alpha_1\beta_2\beta_3 + \alpha_2\beta_2^2 + \alpha_1^2\beta_1\beta_3 + \alpha_2\beta_2^2 + \alpha_1\alpha_2\beta_1\beta_2)}{[(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)]^2} < 0 \quad (24)$$

$$\frac{\partial \varepsilon^{**}}{\partial j_z} = \frac{h_g(h_g j_0 - h_0 j_g)(\alpha_1\beta_2\beta_3 + \alpha_2\beta_2^2 + \alpha_1^2\beta_1\beta_3 + \alpha_2\beta_2^2 + \alpha_1\alpha_2\beta_1\beta_2)}{[(\beta_2 + \alpha_1\beta_1)(h_g j_z - h_z j_g)]^2} > 0 \quad (25)$$

We now assume that each coalition allies with other coalitions to build a more powerful bloc in the political arena. Table 1 gives the combination of parameters emerging from bloc formation.

It is straightforward from the outcomes of bloc formation that either the pro-labor-green or the green-pro-capital coalitions may produce an outcome in which the wage share and the employment rate increase at the same time, assuming $\beta_3 > \alpha_2\beta_1$. To what extent will the outcome improve the wage share over the employment rate, or will the other way round depend on which of the two blocs is formed? The pro-labor-green coalition will have a higher impact on the wage share than the pro-capital-green one (Lauber and Mez, 2004). The pro-capital-green coalition is similar to the so-called Jamaican coalition, in which union interests are less influential than those of the capitalist sector (Mayer, 2009).

4.3. The case of inclusive and sustainable development: the basis of a possible green-pro-labor alliance

Focusing on the US, Doherty et al. (2021) affirm that one of the main issues sustained by the democratic coalition is the belief that the

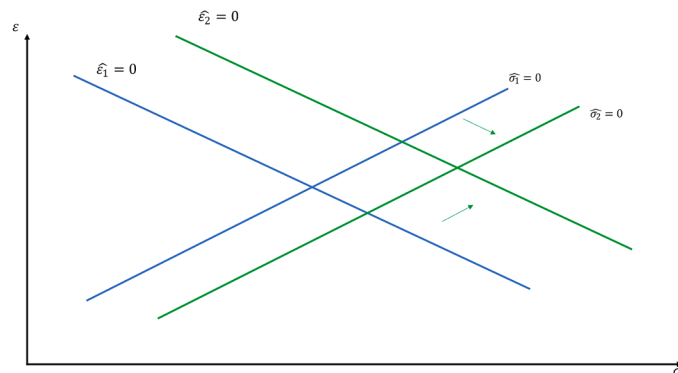


Fig. 7. The just green transition promoted by the pro-labor -green coalition.

economic system disproportionately benefits powerful entities, and it concurs that tax rates should be increased for large businesses, corporations, and wealthiest households. Additionally, there is consensus within the coalition that the minimum wage should be raised. In our model, the parameter α_0 represents the institutional framework in which wage bargaining occurs in the labor market. A policy aimed at raising wages would lead to a more generous welfare state ($\uparrow \alpha_0$), which is more favorable to the worker class attributing them increasing bargaining power. Having more political power, unions can demand a higher wage by pushing the wage share up and the employment level down, shifting the isocline $\hat{\sigma} = 0$ in Fig. 7.

Porter and Van der Linde (1995) affirm that environmental regulation can increase firm competitiveness, encouraging the adoption of environmental innovations. The high green technology gap implies that most of the employment and exports are in the hands of the brown coalition, which has an interest in maintaining the status quo, which, especially in developing economies, may lead towards encouraging low-tech sectors where labor costs are lower and characterized by greater price competitiveness. On the contrary, more citizens have more political power to require more environmentally friendly policies in a more equitable society (Wan et al., 2022). Fredriksson (1997) argues that the number of environmental lobbies positively affects the stringency of environmental regulations according to the level of political competition. This means that more political power is concentrated in the hands of green coalitions supporting proactive climate policies in countries with more generous welfare regimes.

A pro-labor policy can help change the institutional framework and create a more conducive environment for the green coalition (skilled workers and capitalists). When its political power is high due to the positive influence of international environmental cooperation ($\uparrow j_0$), the economic and political power of the Brown coalition are low ($\downarrow j_g, \downarrow j_z$). As we said at the end of the previous sections, the green coalition has to stimulate the diffusion of environmental innovation to reduce the green technological gap and achieve environmental sustainability. The signs of derivatives suggest that an increase in the political power of the green coalition could produce a positive effect on the wage share, but a negative one on the employment rate. The relocation of resources from brown sectors to green ones probably requires more skilled workers to be paid higher wages, which could exacerbate socioeconomic inequalities, leaving the least skilled workers out of the labor market. Therefore, to minimize this risk, a democratic green coalition should foster not only green technological progress but also a “just” green transition, with a strong concern with income distribution, ensuring the support of unions. This alliance must support environmental innovation to improve the wage share and employment rate simultaneously. Environmental international agreements or green standards could be a powerful instrument represented by the parameter j_0 . However, they can positively influence the employment level only if the ecological structural change promoted by the pro-labor-green coalition is aimed at supporting not only the internal labor market but mostly the international competitiveness of the country, expressed by the condition $\beta_3 > \alpha_2\beta_1$ and shifting the isocline $\hat{\varepsilon} = 0$ to the right. Green technological change can represent an essential driver of international competitiveness: green innovation can improve price competitiveness, reducing production costs, but also non-price competitiveness increasing the environmental performance and quality of products perceived by the international markets (Guarini and Oreiro, 2023). Therefore, the pro-labor-green coalition could spur environmental policies that utilize

environmental protection as a means to foster employment development, creating jobs that are not only environmentally friendly but also decent in terms of their quality and competitive advantages (Yip, 2018).

5. Concluding remarks

There is an increasing awareness of the risks of environmental destruction and rising demands for a transition towards a more sustainable development path. Minimizing greenhouse emissions, green growth strategies have the potential to create income inequality and unemployment if they solely rely on technological advancements and environmental policies. The working class bears the brunt of the consequences of green growth, as the shift towards green technologies necessitates a higher level of skills, thus widening the socioeconomic gap between less-skilled and highly-skilled workers. Moreover, the demand for a green transition also stresses that it should be "fair", in the sense that it should encourage income distribution in the domestic economies and reduce asymmetries between the center and periphery in the global economy. In this paper, we argued that reducing the green technological gap might help simultaneously increase employment levels and wage share. Therefore, it should be a key component in a fair green transition. Mechanisms that facilitate the advancement of sustainable development should be implemented. These include policies and strategies focused on sustainability, educational initiatives, the Clean Development Mechanism (CDM), scientific collaboration, financial assistance, and technology transfer. Focusing on this last aspect, the dearth of knowledge regarding the technology and the scarcity of personnel possessing the requisite experience and expertise impedes the transfer and adoption of the technology (Corsi et al., 2021). Therefore, sustainable strategies should focus on income protection, education, retraining, and creating new green jobs to support unskilled workers who might otherwise resist the transition.

In this paper, we presented a dynamic model which allows for finding a medium-term equilibrium position for the wage share and the employment share in the economy as a function of the green technology gap and the institutions governing wage negotiations and shaping the bargaining power of unions and firms. In the long run, the green technology gap is driven by the initial level of the gap itself and the political power of a green coalition. The green technological gap affects the economy's structure and the relative power of firms and skilled workers in green sectors to that of firms and unskilled workers in brown sectors. The implicit assumption is that the direction of green technical change is towards green innovation, and green sectors and activities are more technology-intensive than brown ones.

Reducing the green technological gap will certainly increase the wage share, while it will positively influence the employment rate only if the impact of the "ecological structural change" on the non-price competitiveness is higher than its impact on the price competitiveness. The model highlights how successful green transitions depend on forming political coalitions that can support green policies. This includes alliances between green capitalists, skilled workers, and trade unions. These coalitions can help push for the necessary institutional changes and investments in green technologies. Indeed, the ecological transition process has spontaneously occurred within dynamic growth models, where political coalitions play a significant role (green vs brown). For example, major international institutions such as the OECD, European Commission, IEA, IMF, WEF, NGOs, billionaires, and influential think tanks are all endeavouring to direct capital into the "green sector" to achieve a "green economy". For this diverse group, the change in trajectory primarily depends on green investment. In particular, 26 prominent development and central banks established the International Development Finance Club to advance "climate finance" and "green banking" in 2011 (Magalhães, 2021). Therefore, policies should promote green technological innovation to enhance non-price competitiveness, considering the power relations between opposite political coalitions, which could result in fragile institutional change. Moreover,

introducing a sustainable goal in the model, such as the level of greenhouse emissions, highlights the complexity of the ecological transition and the need not to dwell on the technological dimension alone. The ILO (2015) Just Transition Guidelines propose that transitioning to a zero-carbon economy can be achieved equitably, addressing entrenched social inequalities. This vision emphasizes fairness and inclusivity in the shift towards environmental sustainability. Furthermore, as suggested by the possible adverse effects of green jobs, the ecological transition could be a new source of inequality. Since this paper focuses on the interaction between economic growth's technological and political dimensions, further research could extend the model by including social sustainability. In particular, to make the model more instrumental for the political economy, it will be necessary to develop the analysis further in the future by introducing environmental and social metrics that could provide a more comprehensive view of its impact, such as on carbon emissions and social inequality.

In the long-run equilibrium, only the low velocity with which the technological frontier moved concerning the periphery, the low capacity of the brown coalition to translate its economic power into political power, and the high ability of the green coalition to prevent the countervailing forces of the brown coalition allow the economy to achieve a stable equilibrium characterized by a lower green technological gap and more significant political influence of the green coalition. An increase in the political power of the green coalition could produce a positive effect on the wage share, but a negative one on the employment rate. To achieve inclusive and sustainable development, a democratic green coalition would be desirable, fostering green technological progress and a "just" transition. Policies should focus on providing support to this coalition and prevent unskilled workers from aligning with brown capitalists to block the transition. Since the early 1990s, labor union participation in global environmental negotiations has become more systematic, endeavouring to substantiate the social dimension through the core principles of labor environmentalism, namely "just transition" and the promotion of decent green jobs. For instance, the International Transport Workers' Federation sustains that a just transition demands democratizing social and economic relations to prioritize human and planetary needs over profit and strong pressure from trade unions and societal allies is essential, with workers and communities playing key roles (Steviss and Felli, 2015). Therefore, the political strategy mentioned above entails the direct involvement of trade unions in setting targets and timing, expanding green awareness in the labor market and cooperating with both institutions and enterprises to find practical solutions and effective actions in terms of the sectoral and international division of labor. It could spur environmental policies that utilize environmental protection as a means to promote employment development, creating jobs that are not only environmentally friendly but also decent in terms of their quality and competitive advantages.

The great difficulty from a political economy perspective is how to overcome the endogenous forces that preserve the economy towards low-tech sectors. Introducing the political dimension in the model, a stable equilibrium emerges assuming that there are decreasing returns to the accumulation of power, which means that there will be growing demands in favor of the green transition even in laggard economies, and brown interests will remain a significant player even in green economies. Developing green technologies is multifaceted, and many countries cannot accomplish it solely through their domestic capabilities. To achieve diversification in green technology, it is often necessary to access foreign expertise and cultivate the requisite endogenous domestic capabilities, which typically necessitates international linkages and cross-country cooperation. In particular, several studies show that international sources of knowledge are especially advantageous for late-comer economies, enabling them to catch up with leading nations in various sectors and technologies, including green technologies (Corrocher et al., 2024). From this perspective, the paper supports the idea that policies should promote global partnerships and local coalitions to address environmental sustainability and social inclusiveness.

It is argued that international cooperation in favor of technological catching up in green technologies in the periphery, as well as institutional change favoring stronger social protection and faster technological diffusion, should be at the core of the agenda for a fair green transition. Positive feedback between green innovation and income distribution would help to strengthen a green coalition in the face of the pressure of the brown coalition. Further research could fruitfully explore and analyze more in-depth the effects of the political conflict between several coalitions and alliances on the labor market to identify possible paths towards the “just transition” claimed by trade unions, also by evaluating different real-world case studies. Moreover, some emerging economies perceive the new energy sector as an opportunity to address environmental protection pressures while stimulating economic growth. However, the technology gap in the new energy industry is relatively smaller than that in the ICT industry, facilitating more leisurely catch-up or even overtaking of developed countries by emerging economies (Xu et al., 2020). Therefore, further research could analyze the role of these new emerging technologies in the catching-up process. Moreover, a limitation of the paper is to have considered only the dichotomy between green and brown coalitions. This choice allowed us to simplify the analytical framework and provide clearer results that may help illuminate the forces at work in more complex scenarios. We believe that including a higher diversity of actors and interests shaping the policies of the ecological transition and social sustainability is an interesting topic for future research, perhaps using models with many heterogeneous agents. For instance, redefining sustainability transition and political ecology’s insights on conflict, power, and justice through Gramscian hegemony theory, Kalt (2024) suggests a Gramscian political ecology, which emphasizes the significant roles of marginalized groups and overlooked agents, like climate justice movements and trade unions, in initiating conflicts, challenging power structures, and promoting just

sustainability transitions. With this perspective, this paper could stimulate interdisciplinary studies in which the melding of political science with economics could enhance the understanding of the significant role of political power dynamics in technological adoption and environmental policy; indeed, the ecological transition could also be interpreted as an epistemological challenge for the social sciences in terms of ends, instruments, methods, concepts.

CRedit authorship contribution statement

Chiara Grazini: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Giulio Guarini:** Conceptualization, Data curation, Formal analysis, Software, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Jose Gabriel Porcile:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. They state that no financial assistance was received for this article. The authors declare that there are no patents or copyrights to be asserted that are relevant to the work in the manuscript.

Data availability

No data was used for the research described in the article.

Appendix A. The stability analysis of the dynamic system without political power of the green coalition

The equilibrium point of the dynamic system is formally given by:

$$\begin{cases} \hat{\sigma} = 0 \\ \hat{\varepsilon} = 0 \end{cases} \begin{cases} \alpha_0 + \alpha_1 \varepsilon - \alpha_2 Z - \sigma = 0 \\ \beta_0 - \beta_1 \sigma - \beta_2 \varepsilon - \beta_3 Z = 0 \end{cases} \begin{cases} \sigma = \alpha_0 + \alpha_1 \varepsilon - \alpha_2 Z \\ \varepsilon = \frac{\beta_0 - \beta_1 \sigma - \beta_3 Z}{\beta_2} \end{cases} \begin{cases} \sigma^* = \frac{\alpha_0 \beta_2 + \alpha_1 \beta_0 - Z(\alpha_1 \beta_3 + \alpha_2 \beta_2)}{\beta_2 + \alpha_1 \beta_1} \\ \varepsilon^* = \frac{\beta_0 - \alpha_0 \beta_1 + Z(\alpha_2 \beta_1 - \beta_3)}{\beta_2 + \alpha_1 \beta_1} \end{cases}$$

Once we identified the equilibrium point, we verified its stability by building the Jacobian matrix:

$$J = \begin{bmatrix} -1 & \alpha_1 \\ -\beta_1 & -\beta_2 \end{bmatrix}$$

To be stable, the system must respect two conditions:

- I. The trace must be negative $T|J| < 0 : -1 - \beta_2 < 0 \rightarrow \beta_2 > -1$
- II. The determinant must be positive $Det|J| > 0 : \beta_2 + \alpha_1 \beta_1 > 0 \rightarrow \alpha_1 > -\frac{\beta_2}{\beta_1}$

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