Institutional Change and Just Transition

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Abstract

The paper presents a structuralist model that discusses the political power dimension of the just transition. The urgent concerns about income distribution and environmental degradation have spurred growing academic attention toward exploring the correlation between socioeconomic inequalities and environmental sustainability (Chen et al., 2022). A rapid green transition based on Ecological Technological Progress and Ecological Structural Change can effectively tackle the environmental issue (Guarini & Oreiro, 2022). The distribution of political power among different coalitions determines which institutional framework is implemented. On one side, there are "brown" sectors (BS) whose share in value-added and employment should contract or disappear; on the other, "green" sectors (GS) whose share should increase. However, reallocating resources from BS to GS could bring out "winners and losers", reinforcing vulnerabilities and inequalities (Sovacool et al., 2021). To avoid negative effects on employment, labor unions are advocating for a "Just Transition" ensuring income protection, re-training, and creation of high-quality "green jobs" (Clarke & Sahin-Dikmen, 2020). Nonetheless, reorganising the production system necessary for the green transition requires substantial subsidized investments in GS in the short term. (Stilwell, 2021). Environmental regulations, such as taxes and subsidies, can theoretically encourage the adoption of green technologies, but it remains uncertain whether they can genuinely serve as a stimulus for firms and their effect on employment (Tchórzewska et al., 2022). Implementing a BOP-constraint growth model, this paper tries to respond to a political economy problem: how the political conflict between brown and green capitalists can affect the introduction of environmental regulation and how to prevent unskilled workers from joining forces with brown capitalists to block the green transition. Analysing the dynamic between institutional change and technological change on employment, this paper wants to endogenize the institutional changes related to political conflict between green and brown coalitions. It examines the role of environmental regulations in ensuring a "just green transition". We argue that the interplay between green technical advancements, non-price competitiveness, and employment could foster a positive feedback loop and create a favourable environment for achieving this goal.

Keywords: Green technology gap; Institutional change; Post-Keynesian model; Green job
JEL classification: E12, F43, Q55, Q56

1. Introduction

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 & Pellow

(2021) argue that this framework has led to the concentration of environmental burdens on poor and marginalized communities. Torras & 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: "*technological change and substitution will improve the ecological efficiency of the economy, and that governments can speed this process with the right regulations and incentives*" (Hickel & 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, 2022b). While promoting low greenhouse emissions, a green growth strategy could generate income inequality and unemployment 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 (OECD, 2023; Velicu & Barca, 2020). To avoid the negative effects on employment, workers' unions are advocating for a "Just Transition," ensuring income protection, education, re-training, and the creation of new "green jobs" (Clarke & 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 & Sahin-Dikmen, 2020; Velicu & Barca, 2020). However, restructuring the production system required by the green transition imposes huge investments on capitalists in the short term (Stilwell, 2021). 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 are implemented.

Uncovering the significance of structural change factors is crucial for ensuring sustainable growth (Fabozzi et al., 2022). It depends on the possible interactions between the material and technical characteristics of the production system and on the changes in output distribution among social groups (Cardinale & Landesmann, 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). "*Democratic decision-making implies that these conflicts cannot be decided by a single individual, but some kind of collective agreement has to be reached that usually includes the support of at least a simple majority of the involved actors. Hence, in order to further their own interests, individual actors have to form and maintain coalitions with other actors in democratic decisions*" (Sauermann et al., 2022, p. 13). In the Post-Keynesian framework, Porcile & 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. Building a new theoretical inequality, democracy, and environment, Downey & Strife (2010) observe elite-controlled organizations act to create undemocratic institutions to promote capital accumulation and achieve their goals producing environmental degradation and hindering proenvironmentally behaviours when inequality is high. Following the ecological modernization theory, Shwom (2011) identifies the political relationship between industry coalitions (such as petroleum, coal, natural gas, and electrical utilities) and green transition coalitions (i.e. labor-environmental alliances, urban political constituencies, and green-energy industries) as an essential factor affecting sustainable transition: while incumbent regime acts against Sustainable policies believing that they reduce their profitability in the short term, labor unions appear to exert effective pressure for long-term change (Hess, 2014).

Moreover, Geels & Schot (2007) developed the multi-level perspective framework to understand how technological and social changes interact to shape long-term socio-technical transitions. They argue that incumbent regimes altering the development's trajectory can often hamper transformation patterns. Evidence confirmed by the empirical literature: 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). As Ravallion et al. (2000) suggested, social inequality can potentially hinder the ability to achieve collaborative solutions to environmental issues. While pro-economy groups feel no need for any change, pro-ecology groups see the Swiss energy transition as a growth opportunity advocating for policy intervention and regulation changes (Markard et al., 2016). On the contrary, the greater political power of the first group could result in weaker social protection programs and lower wages (Fitzgerald, 2022).

To avoid falling into the middle-income technological trap, a country must be able to *"keep peace with technological change and innovation*" (Andreoni & Tregenna, 2020, p. 324). The ecological modernisation theory has been employed to depict an environmentally focused policy approach that centers around technology and innovation: the persistent need for environmentally friendly development, in the long run, necessitates a policy approach that prioritizes innovation in environmental technologies (Jänicke, 2008). "*Sustainable technologies are disadvantaged and require strategic support to protect them against premature rejection by investors, customers and users whilst the performance, price and infrastructures for these technologies develop. In evolutionary terms, novel technological varieties with more environmentally friendly and socially just characteristics struggle to develop under unfavourable, multi-dimensional selection pressures*" (Raven et al., 2016, p. 2). To achieve an energy-just transition, the labor unions advocate an energy policy supporting clean technologies such as carbon capture systems and increasing renewable energy sources (Clarke & Sahin-Dikmen, 2020). Many of these technologies necessitate significant upfront capital investments, often accompanied by an upturn in variable production costs. Consequently, from a purely economic standpoint based on current prices, the investment in such technologies often lacks justification.

Policymakers should use political tools to encourage the adoption of green technologies (Krass et al., 2013). Green or environmental fiscal policies are increasingly being adopted because they can internalize the social costs of negative externalities in production. They can potentially become a significant driver for technological innovation and international competitiveness. Environmental or green fiscal policies can fulfil two roles: first, by incorporating the costs of externalities into the prices of polluting goods and services, and second, by promoting employment, improving income distribution, and encouraging the development of new technologies that reduce energy consumption and the use of natural resources (Luìs et al., 2020). Although the literature theoretically sustains the hypothesis that environmental regulations can support the adoption of green technologies, it is not clear whether these can represent a real stimulus for companies to invest in these technologies (Tchórzewska et al., 2022). Implementing a theoretical Stackelberg game, Krass et al. (2013) identify a possible reverse effect: while they initially could incentivize a transition towards more environmentally friendly technology, subsequent overly tight tools could push toward dirty technologies. At the same time, their effect on employment is uncertain: Yip (2018, p. 2) identifies a negative relationship because "*environmental taxes decrease firms' profits and thus labor demands. On the other hand, the tax revenues are recycled through other tax reductions, which may then increase firms' profits, thereby increasing labor demand*"; Domguia et al. (2022) detect a positive influence on total employment creating the condition for technological progress, increasing innovation and production efficiency, and supporting the emergency of new green activities, jobs, and sectors.

In theory, more citizens have more political power to require more environmentally friendly policies in a more equitable society (Wan et al., 2022). 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. Grabowski (2013) argued that groups with diminished political influence would impede technological progress. However, the "big green mainstream organizations" have been widely criticized for their inability to create a strong political base capable of responding to the needs of those most vulnerable to environmental disasters (Ciplet & Harrison, 2020).

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). Any green development strategy must establish an eco-developmental class coalition formed by workers, entrepreneurs, and institutions (Dávila-Fernández & Sordi, 2020a; Guarini & Oreiro, 2022). 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 & Sanchez-Ancochea, 2021). Coalitions can influence public policies and organizational and technological decisions (Hess, 2018). 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. In the auction model for an open economy, Fredriksson (1997) argues the number of environmental lobbies positively affects the stringency of environmental regulations according to the level of political competition. In the environmental justice framework, Farrell & Stano (2021) observe that some environmental justice movements have opposed their introduction, unable to guarantee an inclusive process. Focusing on polluters, Meckling et al. (2015) highlight they have more political interest to form a coalition that opposes a carbon regulation that imposes additional costs on them and distributes the benefits to other stakeholders, but it can favor the growth of green industrial coalitions that will support the development of more stringent environmental policies penalizing incumbent polluters subsequently.

On the empirical side, when a carbon tax is introduced, a conflict between two different alliances could arise (Rennkamp, 2019): on one side, a supporting coalition consists of government, trade unions, and NGOs sustaining a positive contribution to climate change mitigation, poverty reduction, and creation of green jobs balancing out possible job losses in the fossil fuel industry. From above, an opposition is composed of polluters and their business organizations, affirming a reduction in competitiveness, economic activities, and growth. Examining the African context, Resnick et al. (2012) highlight industries' lobbies might object to them as they might erode their international competitiveness against countries that do not apply similar environmental policies and labor unions due to higher energy tariffs.

Supporting the just transition, Gould et al. (2005, p. 11) argue for a possible pro-capital -green coalition between labor unions and environmental organizations, claiming the transition toward greater environmental sustainability occurs equitably for workers, for example imposing "*taxes on toxic-related products that would be used to support workers (unemployment insurance, re-training) whose jobs are lost because of environmental regulations and/or transitions to environmentally friendly production process*". Otherwise, the green transition could be supported by a "*coalition of the winnings*" including influential segments of capital that stand to gain tangible benefits from a fresh wave of low-carbon economic expansion, for example, a green-brown coalition (Newell, 2015). Applying a menu auction model, Canton (2008) observes that eco-industry lobbies push for more stringent environmental regulation, expecting an increase in their profits, while polluting firms claim lower environmental regulation. 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*". This political coalition could promote the development of an institutional setting to face the possible social inequalities produced by the ecological transition (Gatti, 2022b).

Institutional changes are driven by power relations and conflicts between opposite political coalitions, but unbalanced power relationships between coalitions could result in a very fragile institutional change (Rennkamp, 2019). Contributing to the theoretical literature on green structural change in an open economy and the PK literature, this paper wants to endogenize the institutional changes related to green growth. It examines the role of environmental regulation in ensuring a "just green transition" within the endogenous institutional change and political conflict between green and brown political coalitions. Besides this introduction, the paper is organized into three other sections. Section 2 develops a green version of the Balance of Payment-constraint growth model (BOPCG), and section 3 extends the analysis by introducing in the model a political conflict between brown and green coalitions of firms and workers on the implementation of an ecological structural change to stimulate the diffusion of green technologies. The last section contains concluding remarks.

2. The green technological gap in a structuralist model

This section introduces a green technological gap within the structuralist model developed by Porcile & 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 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 & 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):

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

It depends positively on the level of employment rate (ε) and the institutional framework and negatively on the green technological gap (Z). 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 & 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. Finally, the parameter α_2 translates the impact of the green technology gap on the dynamics of the 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. 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). In Figure 1, $\widehat{\sigma_1}$ 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:

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

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

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

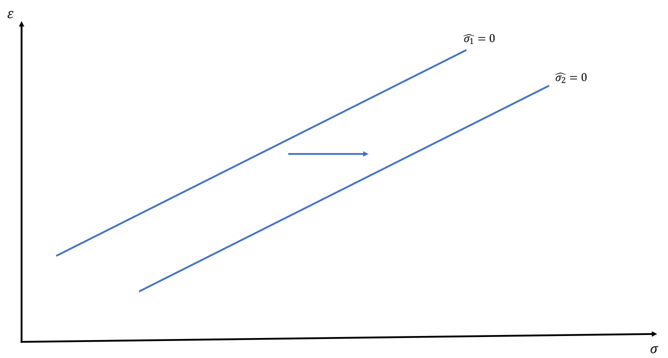
Policies promoting green growth are expected to decrease the need for environmentally harmful end products and intermediary production goods, leading to a decline in labor demand within brown industries (Jackman & Moore, 2021). "*This green Keynesianism aims at the creation of green and decent jobs rather than capital-intensive innovations that casualize work for millions of people*" (Stevis & Felli, 2015). 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 & Barry, 2017). Consoli et al. (2016) highlight green jobs require higher non-routine cognitive abilities and interpersonal skills. If it is indeed the

[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).

case that workers in green industries possess specialized skills, it is plausible to observe higher wages in green sectors (Jackman & Moore, 2021).

Therefore, if the green technological gap is reduced, the expansion of green sectors requires more skilled workers who demand a higher real wage on 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.

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



The BOPCG model assumes that export growth fundamentally determines the long-term growth output, while the trade account maintains its equilibrium (Vera, 2006). In the BOPCG model, the second constraint to wage share negotiation is related to the equilibrium on the external market because the equilibrium growth rate of an economic system must align with the balance of payment (Spinola, 2020). According to the Thirlwall law, the growth rate of an economy is determined by the product of the income elasticity of demand ratio between exports and imports and foreign growth. The following equation gives the employment level:

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

According to technology gap models, enhancing a country's absorptive capability through industrial policy can accelerate the learning rate in the lagging economy. As learning reduces the technology gap and enables catching up in technology, the economy becomes more diversified and better equipped to overcome external constraints on growth, increasing income per capita (Cimoli et al., 2019). Therefore, these models provide a framework for understanding how institutional changes can stimulate or hinder learning, capabilities, specialization, and growth. The parameter represents the effect of an institutional change β_0: a positive institutional change that favors the improvement of the country's technological capabilities and the specialization of production would cause a shift to the right of the curve $\hat{\varepsilon} = 0$. The term β_2 is linked to the following assumption: with the global economy expanding and strict international certification standards or growing consumer awareness of environmental issues, there is a higher demand for "*green products*" compared to conventional goods. Consequently, higher environmental efficiency is expected to be linked to enhanced non-price competitiveness, resulting in increased exports, employment rate, and growth rate of output (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,

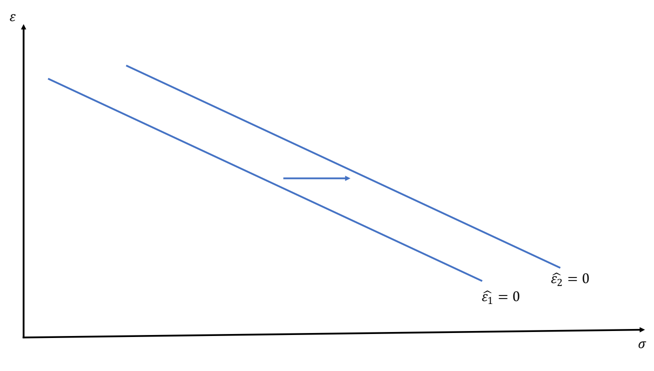
the economy's growth rate (Guarini & Porcile, 2016). Competitiveness depends on both price and non-price characteristics, in particular technological capabilities. The formers are expressed through the parameter β_1. The latter and specialization patterns are essential drivers of non-price competitiveness, or the country's ability to compete through innovation, quality, and other factors that do not depend on the price competitiveness. So β_3 represents the impact of "ecological structural change on international competitiveness".
As shown in Figure 2, the equilibrium in the external market is represented by the curve $\widehat{\varepsilon_1} = 0$, which implies:

$$(6)\ \hat{\varepsilon} = 0: \quad \varepsilon = \frac{\beta_0 - \beta_1\sigma - \beta_3 Z}{\beta_2}$$

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 deficit in the current account. To reduce the deficit and improve competitiveness, it is necessary to cut back 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 & Sanchez-Ancochea, 2021).

According to Spinola (2020), countries specialising 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 $\widehat{\varepsilon_2} = 0$ (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 & 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.

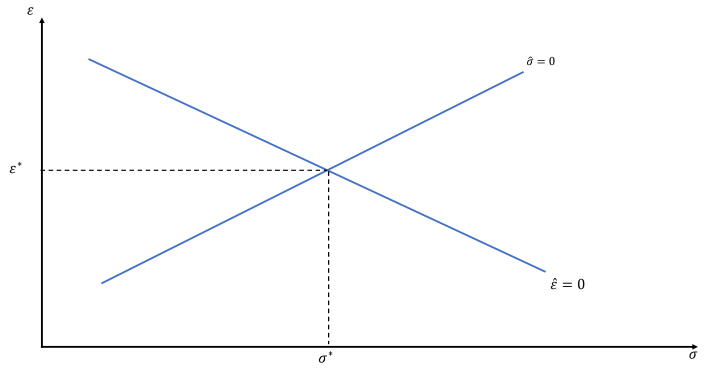
Figure 2. Equilibrium in the external market and the reduction of the green technological gap.



Once the characteristics of each market have been defined, we can identify the solution of the dynamic system which guarantees the simultaneous equilibrium on the domestic and external sectors (see Figure 3), whose stability analysis is contained in Appendix A:

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

Figure 3. The medium-term equilibrium.



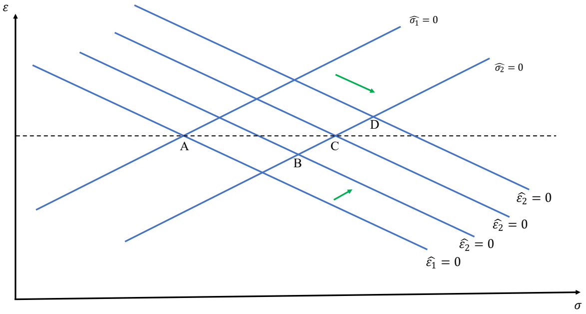
The impact of a reduction of the green technological gap on the equilibrium of the dynamic system is formally given by:

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

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

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 Figure 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, in point C 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 & Oreiro, 2022). 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 & 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.

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



The ninth Sustainable Development Goal of the United Nations encourages 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). 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 Figure 5). Assuming that the labor force corresponding to the population is equal to 1, we start with the total output of the country:

(9) $Y = \varepsilon\pi$

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 & 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:

(10) $H = Y\gamma$

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

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

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, 2022a). "*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:

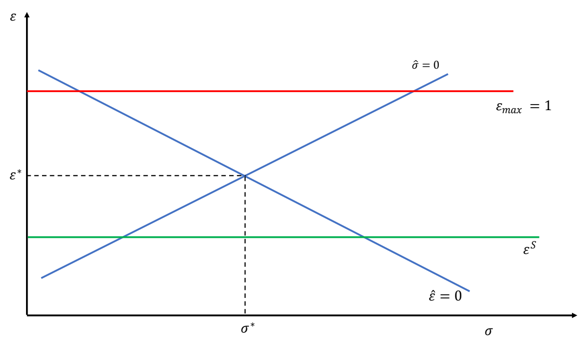
(12) $\varepsilon^S = H^S/\pi\gamma$

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:

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

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 in isolation its technological dimension 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 coalition can condition ecological transition.

Figure 5. The sustainable employment rate.



3. 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. A green coalition 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).

3.1. 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 & 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.

As regards technological change, we will initially assume a linear catching-up model for the green technology gap Z that allows for having higher technological spillovers when the green technological gap is higher. 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:

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

The evolution of the technology gap is captured in equation (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 North[2]; 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 & 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 & Verspagen, 2002). As mentioned, we assume in equation (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 & Uzzell, 2011, p. 1219). If the center adopts an environmental policy that includes green economic restructuring in the periphery, it will not be using its technological capabilities not *"to maximize advantages in trade, but to encourage international technological diffusion.*" (Althouse et al., 2020, p.). 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 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:

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

Environment protection is central in ongoing discussions concerning the international political economy, which requires international cooperation (Luìs et al., 2020). Partnerships are essential, and

[2] Green innovation in the North may be encouraged by more stringent international green standards.

the 17 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 mobilising 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 & 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 equation (15) by the parameter j_0. Institutional changes required to attain social and environmental sustainability pose significant challenges. Efforts for enhancing 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 & Sordi (2020) 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 Dávila-Fernández & Sordi (2022), we can suppose that increasing awareness of the need to start the ecological transition could increase the green technological investments, stimulating the green individual attitudes and the barning power of the green coalitions. As a result, the parameter j_g embeddes the net effect of two different instituional 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 negative[3] ($j_{g1} > j_{g2}$): green attitudes mitigate political barriers but not overcome them.

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

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

To analyse its stability, we estimate the Jacobian of the dynamic system formed by equations (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. $Det|J| > 0: h_z j_g - j_z h_g > 0 \ \rightarrow \ j_z h_g - h_z j_g < 0 \ \rightarrow \frac{h_z}{h_g} > \frac{jz}{jg}$

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 derivates 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:

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

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

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

[3] The importance of political dynamics in defining the equilibrium solution of the model must be stressed. If green attitudes grow excessively throught self-reinforcing mechanisms overcoming political barriers ($j_{g2} > j_{g1}$), we could suppose increasing returns in the green coalition dynamic (see North (1990, 1991) and 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.

Figure 6. Phase diagram of the political economy dynamics.

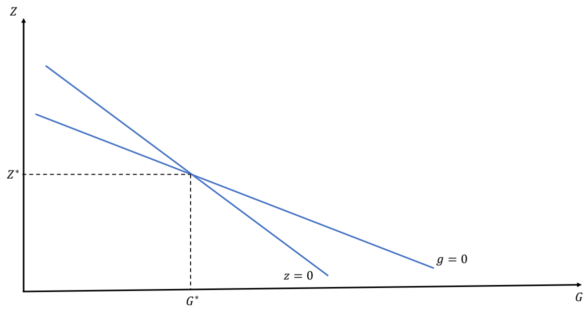


Figure 6 shows the phase diagram of the system of differential equations (14) and (15) in this scenario. Their equilibrium solution will feature a lower Z and a higher G when: i) the velocity with which the technological frontier moved concerning the periphery is lower (low h_0), ii) when the brown coalition has less capacity to translate its economic power[4] 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).

3.2. 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:

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

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

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

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

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

[4] 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.

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 ($\uparrow j_0$, $\downarrow j_g$, $\downarrow j_z$) and the brown coalition ($\downarrow j_0$, $\uparrow j_g$, $\uparrow j_z$). 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 derivates:

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

The stability conditions from the previous systems are:

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

The signs of derivates are:

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

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

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

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

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

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

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

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 ($\uparrow j_0, \downarrow j_g, \downarrow j_z$)	$\uparrow$ σ; $\uparrow \varepsilon$ (only if $\beta_3 > \alpha_2\beta_1$)	$\downarrow\uparrow$ σ; $\uparrow \varepsilon$ (only if $\beta_3 > \alpha_2\beta_1$)
BROWN ($\downarrow j_0, \uparrow j_g, \uparrow j_z$)	$\downarrow$ σ; $\uparrow \varepsilon$	$\downarrow$ σ; $\uparrow \varepsilon$

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 the outcome will improve the wage share over the employment rate, or the other way round will 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 & 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).

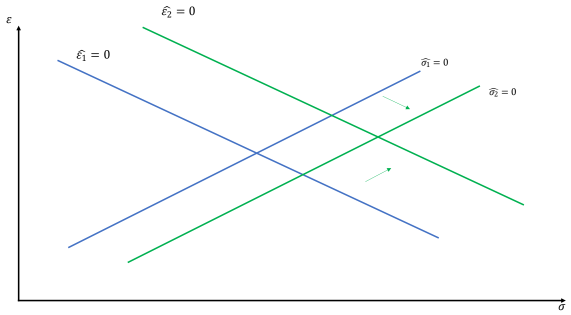
3.2.2. The case of inclusive and sustainable development: the basis of a possible green-pro-labor alliance

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 economic system disproportionately benefits powerful entities, and they concur 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 Figure 7.

Porter & 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, i.e. which especially in developing economies may lead towards encouraging low-tech sectors where labor costs are lower and characterized by greater price competitiveness. 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 ($\downarrow j_0$), 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 derivates 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 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 simultaneously improve the wage share and employment rate. 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 also 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 & Oreiro, 2022). 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).

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



3.3. Empirical analysis

In what follows, we empirically test the ideas suggested in the phase diagram discussing the dynamics of Z and G. In the empirical exercise, we used data for OECD countries in 1990-2020 to capture long-run movements in the green political power and the green technology gap. The econometric method is the feasible generalized least squares estimator (FGLS) to control for heteroscedasticity and serial correlation of the error term.

Changes in the green technological gap equation $z = h_0 - h_g G - h_z Z$ is approximated by the following two equations:

i) $\text{d.EPATGAP} = \alpha_1 + \beta_1 \text{EPATGAP\_1} + \gamma_1 \text{EPS\_1} + \delta_2 \text{POP\_1} + \varepsilon_2 \text{d.GDP\_1} + \varphi_2 \text{EU} + \sigma_2 \text{time} + \tau_2 \text{time}^2$

ii) $\text{d.EN\_EF\_GAP} = \alpha_2 + \beta_2 \text{EN\_EF\_GAP\_1} + \gamma_2 \text{EPS\_1} + \delta_2 \text{POP\_1} + \varepsilon_2 \text{d.GDP\_1} + \varphi_2 \text{EU} + \sigma_2 \text{time} + \tau_2 \text{time}^2$

Changes in the clout of the green coalition stated in equation $g = j_0 - j_g G - j_z Z$, is approximated by the following two equations

iii) $\text{d.EPS} = \alpha_3 + \beta_3 \text{EPATGAP\_1} + \gamma_3 \text{EPS\_1} + \delta_3 \text{POP\_1} + \varepsilon_3 \text{d.GDP\_1} + \varphi_3 \text{EU} + \sigma_3 \text{time} + \tau_3 \text{time}^2$

iv) $\text{d.EPS} = \alpha_4 + \beta_4 \text{EN\_EF\_GAP\_1} + \gamma_4 \text{EPS\_1} + \delta_4 \text{POP\_1} + \varepsilon_4 \text{d.GDP\_1} + \varphi_4 \text{EU} + \sigma_4 \text{time} + \tau_4 \text{time}^2$

All variables are expressed in terms of logarithms, symbol "d." indicates the difference of logarithms that approximates the growth rate, and symbol "_1" means one year of temporal lag (in Table 2 we will also consider lag 2). The green technological gap is approximated by the "environmental patents gap" (EPATGAP) in equations i) and iii) and by the "environmental efficiency gap" (EN_EF_GAP) in equations ii) and iv). The weight of the green coalition is approximated by the Environmental Stringency Policy Index (EPS) developed by Kruse et al. (2022) only for OECD countries: following Dávila-Fernández & Sordi (2020a), it can approximate green attitudes/green coalition. The control variables are the population (POP), GDP growth rate (d.GDP), a dummy for European Union's countries (EU), and a nonlinear temporal trend (time and time2).

The following two Tables show that the theoretical equations are verified.

Table 2. The dynamic system in time.

	(1) d.EPATGAP	(2) d.EN_EF_GAP	(3) d.EPS	(4) d.EPS
EPATGAP_1	-0.0575***		-0.00595***	
	(-5.64)		(-2.84)	
EPS_1	-0.0529**	-0.125***	-0.0799***	-0.0792***
	(-2.05)	(-4.31)	(-7.39)	(-8.45)
d.POP_1	0.0158*	0.00970	0.00154	-0.00118
	(1.73)	(0.87)	(0.63)	(-0.52)
d.GDP_1	1.001*	-1.106*	0.0505	-0.122
	(1.70)	(-1.81)	(0.37)	(-0.87)
EN_EF_GAP_1		-0.391***		-0.0110**
		(-15.49)		(-2.00)
Constant	YES	YES	YES	YES
EU dummy	YES	YES	YES	YES
Temporal trend	YES	YES	YES	YES
Observations	870	982	956	1001
N_g	39	37	40	39
N_t	28	29	29	29
chi2	39.43112	252.9978	71.35223	89.71148

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table 3. The Dynamic system in time2.

	(1) d.EPATGAP	(2) d.EN_EF_GAP	(3) d.EPS	(4) d.EPS
EPATGAP_2	-0.0342***		-0.00444**	
	(-4.12)		(-2.41)	
EPS_2	-0.0372*	-0.0715***	-0.0497***	-0.0561***
	(-1.71)	(-3.02)	(-5.36)	(-6.79)
POP_2	0.00473	0.0126	0.000653	-0.000233
	(0.61)	(1.36)	(0.31)	(-0.11)
d.GDP_2	0.170	0.458	0.331***	0.316**
	(0.32)	(0.83)	(2.70)	(2.37)
EN_EF_GAP_2		-0.267***		-0.0123**
		(-12.21)		(-2.38)
Constant	YES	YES	YES	YES
EU dummy	YES	YES	YES	YES
Temporal trend	YES	YES	YES	YES
Observations	815	945	935	967
N_g	38	37	40	39
N_t	27	28	28	28
chi2	30.21911	150.3689	54.3239	73.73983

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

4. 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.

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 process of ecological transition has been observed to spontaneously occur within dynamic growth models, where political coalitions play a significant role (green vs. brown). The introduction of 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.

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, the economy can achieve a stable equilibrium characterized by a lower green technological gap and greater 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. 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. It is argued that international cooperation in favor of technological catching up in green technologies in the periphery, and 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 to 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.

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 $T|J| < 0:\ -1 - \beta_2 < 0 \quad \rightarrow \quad \beta_2 > -1$

II. The determinant must be positive $Det|J| > 0:\ \beta_2 + \alpha_1\beta_1 > 0 \quad \rightarrow \quad \alpha_1 > -\frac{\beta_2}{\beta_1}$

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