# Coupling environmental transition and social prosperity: a scenario-analysis of the Italian case.

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**Abstract**

This paper investigates the social and structural conditions grounding the feasibility of green growth policies. It takes the proposal of a *Green New Deal* as a reference and assesses i) whether green investments and innovation will be able to ensure the promised social prosperity and ii) what kind of social policies are able to compensate for the risk of increasing inequality. For this purpose, we develop a dynamic macrosimulation model of the Italian economy which explores the social and structural effects of the Italian integrated policy plan for energy and climate. We find that green growth alone will not result in better societal conditions and needs to be compensated with social policies to reduce inequality. Hence, we select two social policies, namely a basic income programme and a working time reduction policy, that are expected to deliver similar results in terms of redistribution and compare their environmental outcomes in terms of $CO_2$ emissions. Our scenario analysis shows that working time reduction leads to an increase in employment and a parallel decrease in aggregate demand that cause both a reduction in emissions and inequality. On the other hand, the basic income programme reduces inequality by sustaining aggregate demand, which in turn reduces the positive environmental effects of the energy plan.

## 1 Introduction

Green growth – the project of *"making growth processes resource-efficient, cleaner and more resilient, without necessarily slowing them"* (Hallegatte et al., 2011) – stands out as a pillar of worldwide strategies for combating climate change. It is included in the sustainable development goals pursued by the United Nations (Programme des Nations Unies pour l'environnement, 2011) and sustains the project of an "inclusive green economy" (United Nations, 2019a,b). The OECD relies on green growth as a development policy able to *"deliver economic growth that is both green and inclusive"* to developing countries (OECD, 2011, 2015; OECD, 2019). Green growth is also at the centre of the European Commission's development and environmental strategies (European Commission, 2018) and is expected to lead to an *"inclusive green economy that generates growth, creates jobs and helps reduce poverty through sustainable management of natural capital"* both in the EU and globally (Euopean Commission, 2019a,b).

The green growth paradigm finds an application in the political proposal of a Green New Deal (GND, henceforth) for the US economy, advanced by Representative Alexandria Ocasio-Cortez and Senator Ed Markey on February 7, 2019.[1] The two resolutions contain principles and policy indications for a 10-year programme pursuing the objectives of eliminating pollution and greenhouse gas emissions from infrastructures, manufacturing, farming and transportation, of completely switching to clean, renewable and zero-emission energy sources and of maximizing energy efficiency in electricity production and distribution, in buildings, and industries. Accordingly, the GND project views the public investment in greening the US economy as an *"opportunity (1) to create millions of good, high-wage jobs in the United States; (2) to provide unprecedented levels of prosperity and economic security for all people of the United States; and (3) to counteract systemic injustices by making the US economy a prosperous green economy."*

What the GND proposal adds to the green growth approach is the acknowledgment that the environmental issues faced by modern societies are interwoven with social ones, especially with inequality and social exclusion. Climate change and environmental damage are seen as a threat mainly afflicting the more vulnerable part of society and hence as a cause of inequality. Moreover, it is implicitly admitted that the economic growth driven by the GND – as it was for Roosevelt's New Deal – may be beneficial only to the middle and upper classes and exclude poorer citizens (US Congress, 2019a, p. 4-5). For these reasons, GND includes specific policy indications to ensure democratic participation, work rights and

[1] Resolutions H. Res. 109 and S. Res. 59 (US Congress, 2019a,b).

*"family-sustaining wages"*, the satisfaction of basic needs (e.g. health and food) and equal opportunities (e.g. education) for all people in the US.[2]

The scientific debate behind green growth has been reactivated by the GND and mainly focuses on whether decoupling of energy-material use and economic growth will be actually feasible. This debate sets aside the social and structural conditions under which such an attempt to green the economy may be pursued. In this paper we apply a macrosimulation model to clarify the social impacts of green growth strategies and to show that the achievement of environmental goals may be either complemented or slowed down by alternative social policies.

For this purpose, we take the Italian economy as a case study and simulate the Italian energy plan called *"National Integrated Plan for Energy and Climate"* (PNIEC) published at the end of 2018 as an example of green growth strategy (Ministero dello Sviluppo Economico, 2018). Our exercise consists in exploring how policies which aimed at improving efficiency and developing renewable energy sources impact socio-economic indicators and structural change. Furthermore, we integrate this analysis by simulating the effects of alternative policies that may complement energy policy to hinder inequality. This addition sheds light on whether such policies may a) improve the social outcomes of the energy policies and b) provide favourable conditions to achieve the environmental goals themselves. In particular, we take into consideration two social policies that affect employment and income distribution through different channels: a *basic income* (BI) and a *working time reduction* (WTR) policy

Our general aim is to show that the socio-economic and structural impacts of environmental policies are not negligible and may make such policies difficult to implement. Our model makes it clear that pursuing growth through energy efficiency plans alone will not improve socio-economic indicators and does not contribute to reducing inequality. While both simulated social policies, when coupled with the environmental ones in the simulated scenarios, result in significant reductions in income inequality, the *BI* also makes it harder to achieve environmental goals due to increased aggregate demand and production. The opposite holds once *PNIEC* policies are coupled with *WTR* since total demand and production is reduced as a result of a lower, albeit much better distributed, income per capita.

The rest of the paper is organized as follows. Section 2 places our theoretical contribution in the context of the decoupling debate. Section 3, while presenting the model, points out the main differences with other models supporting the predictions of *PNIEC*. Section 4 presents the simulation results of our three policy scenarios with respect to a baseline. Section 5 discusses these results and concludes.

# 2 The decoupling debate

Green growth has emerged as the scientific paradigm in which sustainability policies have been mainly discussed in the policy arena. Its theoretical tenet is that market incentives foster technological efficiency via innovation and the expansion of renewable energy which in turn may fuel economic growth. Accordingly, green growth theorists maintain that technological substitution will allow energy-material consumption and carbon emissions to be decoupled from economic growth (Aghion et al., 2009; Hallegatte et al., 2011; Andreoni and Galmarini, 2012). On the other hand, environmental scientists, ecologists and interdisciplinary researchers refute the possibility that the market may adjust the socio-economic process so as to reduce the material footprint (Wiedmann et al., 2015) and avoid overshooting the planetary boundaries (Steffen et al., 2015) as well as critical transitions (Scheffer et al., 2012).

The political proposal of the GND has stimulated the scientific debate about the desirability of green growth (for a review see Seaton, 2019). Robert Pollin revisited his argument in favour of green growth (Pollin, 2015, 2016), arguing in favour of the GND and opposing de-growth (Pollin, 2018a). His argument is based on two theoretical assumptions. The first is that decoupling economic growth and energy-material use will actually be possible[3]. The second is that new investments in sustainable production and consequent overall growth will increase overall living standards and reduce inequality by supporting employment in countries at all levels of development (Pollin, 2018b).[4] Growth is seen not only

[2]These indications are translated by the labour supporters of the US GND into the concrete proposals of universal health insurance, basic income and job guarantee (Brecher, 2019).

[3]Specifically, according to Pollin, the economy will be able to grow along an environmentally sustainable path thanks to the substitution of oil, coal and natural gas with clean energy and the improvement in energy efficiency. Hence, the green new deal should be developed through an investment of between 1.5 and 2% of global GDP per year in green growth in order to obtain a 40% cut in global $CO_2$ in twenty years' time (and eventually the elimination of emissions in fifty years).

[4]However, Pollin and Callaci (2016) acknowledges that energy transition will also cause job losses and a decline in welfare for communities tied to fossil-fuel industries. This makes it necessary to complement the green new deal project with policies aimed at supporting workers and communities that will suffer the consequences of the abandonment of fossil fuels.

as a desirable outcome, but also acts as a driving force since higher levels of GDP will further sustain future investments toward decoupling.

Pollin's position has triggered the reaction of de-growth advocates who have pointed out the shortcomings of the GND project and the need to decouple energy transition from economic growth (Kallis, 2019; Burton and Somerville, 2019). Kallis (2019) provided counterarguments to Pollin's position by highlighting inconsistencies in the foundation of the Green New Deal in (green) growth. First, while admitting that a higher growth level may translate into higher investments in clean-energy activities, it is also likely to cause even more investments in non-green activities. Secondly, while shifting to a renewable energy infrastructure in a short time span is difficult at the present growth scale, it will be *a fortiori* more difficult at a larger scale. Thirdly, the 2% of GDP investment does not require deficit spending (it could be achieved by replacing non-clean or socially detrimental investments such as armaments) and consequently it does not require growth to be compensated. Fourthly, the shift from fossil fuels to the clean-energy economy entails a transition from a capital-intensive, high-productivity and high-profit industry to a labour-intensive, low-productivity and low-profit industry, which in turn hardly implies growth. Lastly, the relative reduction in $CO_2$ emissions due to the increase in energy efficiency and the change in the energy mix may be rapidly offset by the absolute increase in $CO_2$ emissions in the event of growth.

Numerous studies point out the non-negligible energy-material costs connected to the transition to clean energy and dispute green growth expectations about the feasibility of absolute decoupling, especially if growth further fuels energy demand. Hickel and Kallis (2019) collect relevant evidence showing that a) absolute decoupling of GDP growth and resource use cannot persist in the long run at the global level, but only modestly in high-income countries under unrealistic assumptions concerning technical efficiency gains, and b) while absolute decoupling of GDP growth and $CO_2$ emissions is theoretically possible and is actually occurring in some regions, due to economic growth, it cannot be achieved in time to respect the Paris agreement on the carbon budget for 1.5 - 2 degrees centigrade. Clack et al. (2017) estimate that going 100% renewable is not sustainable as a path towards a low-carbon-emission energy system. Actually, the extent of substitution between renewable and fossil fuel sources is very limited (York, 2012) and does not result in a significant reduction in $CO_2$ emissions (Thombs, 2018). Overall, the increase in investments (and growth) is proved to be tied to higher carbon emissions by Burke et al. (2015).

A further argument against decoupling is advanced by Schor and Jorgenson (2019) who point out that green growth is already worsening global inequality. The reported evidence shows that decoupling is occurring only marginally in developed countries, while in developing countries growth is continuing apace with higher emissions due to a shift towards energy-intensive technology (Jorgenson et al., 2019). The social impacts of green growth are also highlighted by a recent report by the *Institute for Sustainable Futures* of The Sydney University of Technology which describes how renewable energy sources are mainly based on massive extraction of minerals whose costs are mainly incurred by vulnerable communities and workers (Dominish and Teske, 2019).

The relationship between environmental and social issues is bidirectional. For example, climate change is identified in the literature both as a cause and an effect of inequality. Indeed, not only is climate change expected to widen global inequality (Burke et al., 2015) but inequality also results in environmental degradation (Boyce, 1994). The circumstance that inequality may prevent the feasibility of sustainable plans is emerging as a crucial problem in environmental and social policy debates (Baland et al., 2018). Departing from the ecological macroeconomic model developed in the EUROGREEN model (D'Alessandro et al., 2018), we study the social impacts of green growth intervention (i.e. the Italian *PNIEC*) and – by testing the effect of complementary social policies – the socio-economic phenomena that conditions its feasibility (while possibly improving its social outcome). Hence, we contribute to the decoupling debate by shifting the focus from an assessment of feasibility centred on environmental effects alone to one that integrates social impacts in order to analyze whether a) green growth is able to guarantee the promised social prosperity and b) which social policies should be coupled to it to obtain an effective green new deal.

# 3 Model

The present model differs from those usually applied in energy transition analysis, including those used to develop the Italian *PNIEC*, in both structure and content. Policy objectives for renewable energy expansion, energy efficiency and greenhouse gas emissions are often simulated in bottom-up general or partial equilibrium models such as TIMES and PRIMES because they contain detailed information on specific technologies and their costs.[5] Thus, bottom-up or hybrid models are particularly suitable to assess the feasibility of new cost-effective technologies for energy generation, storage and distribution for given projections of energy demand and economic activity in general.

By contrast, our model has a top-down structure which endogenously determines GDP, labour demand, income distribution, energy demand and $CO_2$ emissions as a function of investments, consumption, government transfers and technological change. Hence, its top-down structure proves especially suited to the main purpose of this work: i.e. to evaluate the social consequences of the environmental policies proposed in the *PNIEC* as well as to further understand how different social policies such as working time reduction and social transfer programmes can either ease or hinder low-carbon transition.

Therefore, the analysis that follows is, to a large extent, complementary to bottom-up models that project the *PNIEC* policy objectives. Still, it puts environmental policies into perspective by analyzing their interactions with income distribution, employment and growth in two ways. First, the model considers how the impact of the simulated social policies on aggregate and especially energy demand affects the achievement of environmental targets. Second, it is able to assess whether the achievement of environmental targets through investment, increased energy efficiency, electrification and carbon taxes actually impacts the overall level of economic activity, employment and income distribution.

The analysis that follows is based on an extension of the EUROGREEN model (D'Alessandro et al., 2018). We further disaggregated production into 29 industries, increased the level of detail in the energy module and added fully dynamic technical coefficients to the input-output matrix. Following the ecological macroeconomics literature (Rezai et al., 2013; Fontana and Sawyer, 2016), the main features of the model and the key behavioural equations are based on post-Keynesian economics (Lavoie, 2014).

In addition to the 29 industries, households are divided into 13 groups by skill and occupational status. Low, middle and high-skill households transit between four occupational statuses: inactive, unemployed, employed and retired.[6] The last household group is that of capitalists or rentiers that amount to 0.1% of the population and whose income is derived exclusively from financial gains of asset holdings, including dividends. The calculation of the Gini index, which constitutes our main measure of economic inequality, is based on the incomes of these 13 groups. In the next two subsections we discuss the two main novelties of the present model: technological progress and the energy framework. [7]

### 3.1 Technological progress

The process of technological change that increases labour productivity and energy efficiency is endogenously determined in the model. The key modelling choices concerning the innovation process can be elucidated by identifying four steps: *i.* extraction of available new technologies, *ii.* extraction of the technological coefficients, *iii.* cost minimization and choice of techniques and *iv.* implementation.

The first step (*i.*) randomly draws, for each industry, the availability of three technologies: *a.* labour-saving and intermediate inputs-augmenting, *b.* intermediate inputs-saving and labour-augmenting and *c.* labour and intermediate inputs-saving. At each simulated period these three technologies are extracted from random uniform processes. The extraction probabilities are equal for *a* and *b* and lower for *c*.

In the second step (*ii.*) the model extracts the magnitude of the variations in labour productivity and the technical coefficients of the input-output matrix that determine the demand for intermediate goods including electricity and other energy products, from normal distributions whose first two moments reflect actual values of past variations in labour productivity and technical coefficients.[8] It is further assumed that an increase in labour productivity given by technology *a.* also entails an increase in the demand for intermediate inputs per unit of GDP, and thus an increase in technical coefficients. Symmetrically, technology *b.* postulates a decrease in technical coefficients together with an increase in labour intensity. Technology *c.* when extracted in the first step improves both labour productivity and intermediate goods efficiency, thus reducing the output-to-GDP ratio.

Therefore, given the trade-off between the costs of labour and intermediate goods that emerges from technologies *a.* and *b.*, in the third step (*iii.*) industries compare the total costs of each extracted technology and choose the cost-minimizing one. If, for instance, only technology *a.* is available, it will be chosen if, and only if, the reduction in labour costs from increased labour productivity more than offsets

[5] On the difference between bottom-up and top down models see, for instance, Capros et al. (2018).

[6] Moreover, the model allows for transitions between skills as a function of skill-specific unemployment rates.

[7] A full analytical description of the other features of the model is available in the supplementary information of the EUROGREEN model which can be found at the following link: `https://people.unipi.it/simone_dalessandro/eurogreen_project-2/`.

[8] Variations in labour productivity are extracted for each industry, those of technical coefficients for each coefficient of the input-output matrix.

the increased expenditure in intermediate goods – otherwise the cost-minimizing choice is to maintain the old technology. Thus, the extraction of technologies *a.* and *b.* in the first step does not mean that either of them will actually be implemented. Technology *c.*, on the other hand, will be chosen whenever available since it decreases the costs of both labour and intermediate goods.

This process of technological choice introduces interesting dynamics between and within industries in the simulated economy. Labour-intensive (intermediate goods-intensive) industries are more prone to adopt technology *a.* (*b.*) if it is available. However, in time, increases in labour productivity reduce the incentives to adopt further labour-saving technologies and increase those to adopt intermediate goods-saving ones.

The final step (*iv.*) consists in implementing the chosen technologies. These are not immediately applied to the whole industry, but rather gradually implemented in line with the pace of fixed capital renovation. Thus, once again taking technology *a.* as an example in an industry $i$, the actual labour productivity of an industry adopting *a.* will be given by a weighted average between the newly extracted higher labour productivity ($\hat{\lambda}$) and the labour productivity from its older technology ($\bar{\lambda}$) whose weights are defined by new investments in fixed capital ($I_t$) and the stock of older fixed capital after depreciation ($(1-\delta)K_{t-1}$)[9], respectively:

$$\lambda_t^i = \frac{\hat{\lambda} I_t + \bar{\lambda} K_{t-1}(1-\delta)}{K_t} \tag{1}$$

## 3.2 The Energy Framework

The main modelling purpose of the energy module is to convert each unit of monetary output into energy flows and $CO_2$ emissions. We focus on the distinction made by ISTAT between natural resources and energy products used at industrial and residential level. The *natural resources* are directly supplied by the environment and split between renewable ($\sim 65\%$) and fossil ($\sim 35\%$).[10] The energy products are aggregated into four main sources: solid, liquid, gas, and electricity. Only the latter is not air-polluting.[11]

In brief, given the level of real output, in monetary terms, we convert the total production in energy flow by applying industry-specific coefficients of conversion for each energy source. In particular, knowing the level of production, we obtain the total energy use – in tons of oil equivalent (toe) – by energy source and industry. Then we convert total energy use into final energy consumption to obtain the energy which reaches the final consumer (excluding the energy used by the energy industries, including that used for transformation and transmission). This conversion is required to associate the level of air pollution to each sector and source. Indeed, given the energy mix and the source composition, we obtain industry ($i$) emissions per unit of output ($\mathrm{CO}_2^i/\mathrm{Output}_i$), from which we may compute total yearly carbon dioxide emissions ($CO_2 = \sum_i \mathrm{CO}_2^i$).[12]

Regarding the energy transition towards a low-carbon economy, the share of renewable sources depends on green investments and on the activation of energy policies such as electrification, a change in the energy mix and carbon taxes as described below. In each period, a share of investment is earmarked towards green technologies[13]. Moreover, households also invest part of their wealth in efficiency improvements and renewable energy development. This combination of firms' and consumers' investments to expand clean energy and efficiency affects the share of renewable energy in final energy consumption, thus contributing to reduce $CO_2$ emissions.

## 3.3 Data

The data sources employed to calibrate the model are summarized below.

- *Social and National Accounts*[14]: the Italian Institute of Statistics (ISTAT) provides data about the

[9] Note that in the equation below $K_t = I_t + K_{t-1}(1-\delta)$.

[10] Note that, from the ISTAT database, natural fossil resources are not accounted for under $CO_2$ emissions to avoid double counting, since they are transformed into energy products used by the industries.

[11] In particular, *solid* includes coke, carbon and derivatives, whereas *liquid* consists of crude oil, petroleum and refined products, while *gas* mostly concerns natural gas.

[12] In this study, we opt to model $CO_2$ emissions alone instead of total greenhouse gas emissions in $CO_2$ equivalents because the former reflect more accurately the emissions from production and household consumption while the latter include emissions from agriculture which are less responsive to improvements in energy efficiency and the introduction of renewable energy generation.

[13] This share is first calculated to the investments that correspond to the currently installed capacity in renewable energy and then increased once energy policies are activated to reach the target share of renewable energy sources in final energy consumption

[14] The Italian input-output tables can be found here.

inter-industry intermediate and international trade, including information about the final demand, taxation, and value added (wages and profits). The data are consistent with the NACE (Rev. 2) classification[15] and available for the year 2010 and 2014 which we aggregate to build the input-output matrix for the 29 simulated industries.

- *Energy Accounts*[16]: the energy data come from two datasets. The ISTAT-PEFA reports the matrices of supply and demand of energy fluxes (in terajoules) by source for each NACE industry and for households, for the years 2014 and 2015. In particular, the demand for energy is split into two parts, a matrix ($B$) which supplies total use – including final use, losses, non-energy use, and for transformation – of energy, and a matrix ($C$) which reports the share of polluting energy that generates $CO_2$ emissions. We integrate these data with those from the EUROSTAT's energy balance to obtain final energy use and the actual amount of $CO_2$ emissions by source and industry, including the residential sector, from the Air Emission Account (AEA).[17]
- *Government Balance*[18]: ISTAT collects detailed information on public expenditure, debt and revenues from taxation.
- *Labour market data*: productivity, skill-specific wages and employment by industry, fixed capital stock and capital productivity and hours worked are obtained from the EU-KLEMS project database for Italy.[19]
- *Energy prices*: Energy commodity prices and electricity prices, per ktoe in real 2013 euros, are assumed exogenous and are derived from the official Italian *PNIEC* Report (Ministero dello Sviluppo Economico, 2018, p.83).

## 3.4 Policies

This subsection describes each of the individual policies that are combined to form the three scenarios to be compared with the baseline in section 4. The first three policies below, namely electrification, energy mix and carbon tax, are those that replicate the *PNIEC* target of renewable energy generation and energy efficiency which forms our first policy scenario. The last two, basic income and working time reduction, are then combined, one by one, with the three *PNIEC* policies to form our second and third policy scenarios. All the simulated policies are introduced in year 10 of the simulations which corresponds to 2020. Moreover, all policies are gradually implemented in a five-year window until 2025.

- *Electrification* simulates a gradual increase in the demand for electricity by productive industries which substitutes other non-renewable energy products. Simultaneously, this policy increases the share of each non-energy industries' investments in renewable energy generation.
- *Energy Mix* implies that electricity generation from solid and liquid fuels is gradually substituted – until it is phased out in 2025 and 2050 respectively – by natural gas. As in electrification, the energy mix policy also includes an expansion in renewable energy by the electricity generation industry.
- *Carbon Tax* includes a carbon tax of €70 per ton of $CO_2$ emissions, paid by industries not included in the EU-ETS market.
- *Basic Income (BI)* introduces a basic income programme with annual benefits that amount to €6,480 (i.e. 540 euros per month) for all inactive and unemployed low-skill households in the year of the policy introduction. The value of the benefit is then increased in line with the growth of economy-wide average wages. The simulated *Basic Income* programme is neither unconditional nor universal in an attempt to replicate, at least in part, the current proposal of the Italian government to implement an income transfer programme that benefits the lower-income strata exclusively.[20] However, our scenario analysis considers a much larger number of beneficiaries, varying between 7 and 9 million (i.e. about 13% of the Italian population), instead of the one million currently enrolled to receive the benefit which corresponds to 1.7% of the population. Total government expenditure

[15] The detailed classification is available here.
[16] Available here.
[17] A detailed description of the energy balance is found here while data on greenhouse gas emissions are available here.
[18] Available here.
[19] The data are available here.
[20] In Italian, the transfer programme is called *"Reddito di Cittadinanza"* as laid down Decreto Legge 28 gennaio 2019, n. 4.

in the *Basic Income* programme rises from 50 billion in 2020 to 59 billion nominal euros in 2050. We opt to simulate a much larger programme than that actually implemented for the Italian economy to remain in line with the large-scale policies of income distribution and poverty reduction proposed in the American Green New Deal. Consequently, the *BI* simulated in our analysis has large-scale economic effects both in terms of income distribution and economic activity and production.

- *Working Time Reduction (WTR)* gradually reduces weekly working hours from about 39 in 2010 to 25 in 2050. That is, average weekly working hours decline by 0.5 hours per year which corresponds to roughly twice the rate of working hours reduction in Italy between 1900 and 1990 (Huberman and Minns, 2007).

# 4 Results

For the sake of clarity we present the simulated scenarios in four separate subsections: low-carbon transition (4.1), socio-economic impacts (4.2), technological progress (4.3) and structural change (4.4). In each case the baseline scenario is compared to the Italian (*PNIEC*) and to two alternative scenarios that add the above-mentioned basic income programme (i.e., *BI*) and the working time reduction (*WTR*) to the *PNIEC*.

The dynamics of the simulations depend in part on the outcomes of the technological progress adopted by each industry which, in turn, is rooted on a random process. Thus, to avoid arbitrary results from specific extractions, the scenarios plotted below are the averages of 250 simulations.[21]

We assume that the policies start in 2020. Hence in all the figures below our three policy scenarios differ from the baseline starting from that year. Real data for the period between 2010 and 2018, when available, are plotted in red. The navy blue lines represent the *PNIEC* target values that our three energy policies seek to replicate[22].

## 4.1 Energy transition

The *PNIEC* aims to abate environmental impacts by boosting electricity generation based on clean energy sources and fostering energy efficiency. Figure 1 plots $CO_2$ emissions and final energy consumption in the baseline and our three policy scenarios. Our *PNIEC* scenario projects $CO_2$ emission reductions of about 40% by 2030[23], in line with the official Italian plan. In spite of a remarkable reduction until 2035, carbon emissions stabilize afterwards.

Overall, the three policy mixes generate a substantial emission reduction of at least 30% with respect to the baseline which remains around 340 MtCO2eq from the 2020s on. Addition of the two social policies has the opposite effect on $CO_2$ emissions. The *BI* slows down the reduction of $CO_2$ emissions through the increase in consumption and production that follows the income increase directly induced by the policy. On the other hand, the *WTR* policy further reduces emissions, with respect to the *PNIEC* scenario, due to a lower, albeit more equally distributed, per-capita income.

Panel (b) of Figure 1 shows the trajectories of total final energy consumption in the four scenarios. The three policy mixes, which share the same energy policies, project a sharp decrease in final energy consumption until 2050.

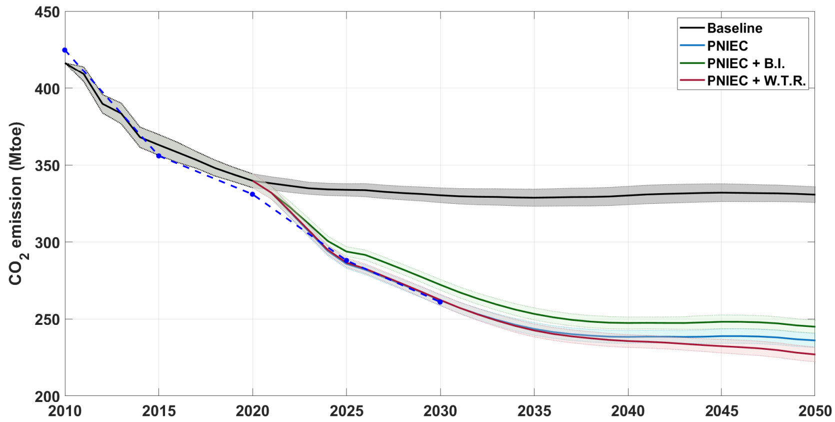
Once again the *PNIEC* scenario lies in between the two social policy scenarios. When the *BI* is integrated, it leads to a higher level of final energy consumption. By contrast, *WTR* leads to a slightly lower energy consumption. Interestingly, the introduction of the *BI* programme causes an absolute increase in final energy consumption – from 2020 to 2026 – due to higher GDP growth and consumption despite the contemporaneous introduction of energy policies. The baseline, in the absence of any energy policies, faces a slight increase in final energy consumption from 2025 onwards, reaching about 110 Mtoe at the end of the simulation period.

The evolution of renewable energy production is presented in Figure 2. It shows the dynamics of the shares of renewable energy on electricity generation (2a) and on final energy consumption (2b). After an initial period in which the trajectories are indistinguishable (until around 2030), the policy-mix scenarios diverge from the baseline. The latter shows only a modest linear increase until 2050, reaching about

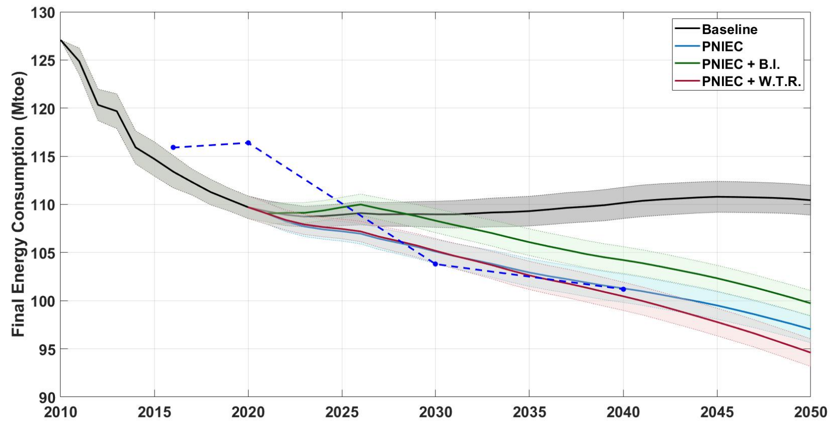
[21] As explained in section 3.1, we select runs with a one-standard deviation confidence interval, from different seeds of the random uniform distributions.

[22] In contrast to our policy scenarios the lines that represent actual values and the *PNIEC* targets are not plotted with confidence intervals around them.

[23] From about 425 to 261 Mtoe.




**(a)** $CO_2$ emissions




**(b)** Final Energy Consumption (Mtoe)

**Figure 1: GHG emissions and Final Energy Consumption.** Comparison – from 2010 to 2050 – of the air pollution (left) and final energy use (right) under the baseline (black) compared with three policy mixes: *PNIEC* (blue), *PNIEC + Basic Income* (green), and *PNIEC + Working Time Reduction* (red). The navy blue dotted line, until 2030, represents the values projected by the official *PNIEC* plan. The shaded areas around the lines indicate one standard deviation confidence intervals.

42% and 25% of renewable energy in electricity and energy consumption, respectively. The three policy-mix scenarios, on the other hand, generate a significant increase in energy production from renewable energy sources whose share in electricity production reaches 90% in 2040, while in energy consumption it continues to increase until 2050, reaching roughly 43%. Unsurprisingly, there are small differences between the *PNIEC* and the two social policy scenarios since they share the same energy policies. Still, the additional aggregate demand from the *BI* increases the total energy demand which results in lower shares of renewable energy.[24] As in figure 1 the *PNIEC + WTR* scenario also outperforms all the others in terms of renewable energy production due to lower overall GDP growth.

## 4.2 Socio-economic impacts

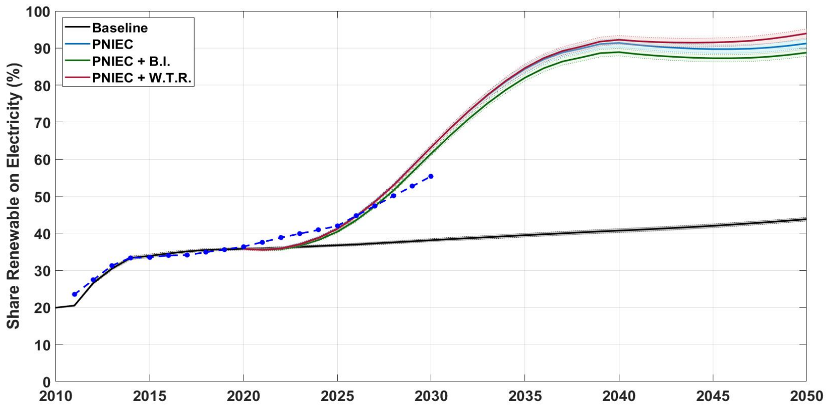
Figure 3 plots the trajectories of national per capita income (3a), GDP growth rates (3b) and the government deficit-to-GDP ratio (3c). The GDP per capita increases in each scenario from 2020 onwards, including the baseline, with the highest values observed when *BI* is simulated. *WTR* curtails economic growth with respect to the other two policy scenarios and remains closer to the baseline. The results in 3a and 3b illustrate the impact in terms of growth of the two social policies which are in line with the results concerning final energy consumption discussed above.

[24] Since the energy policies are the same, the total installed capacity from renewable energy sources is the same in *PNIEC*, *PNIEC + BI* and *PNIEC + WTR*, unlike the demand for electricity and total energy consumption, since the latter depends on the level of aggregate demand in the economy which is directly affected by the two social policies.

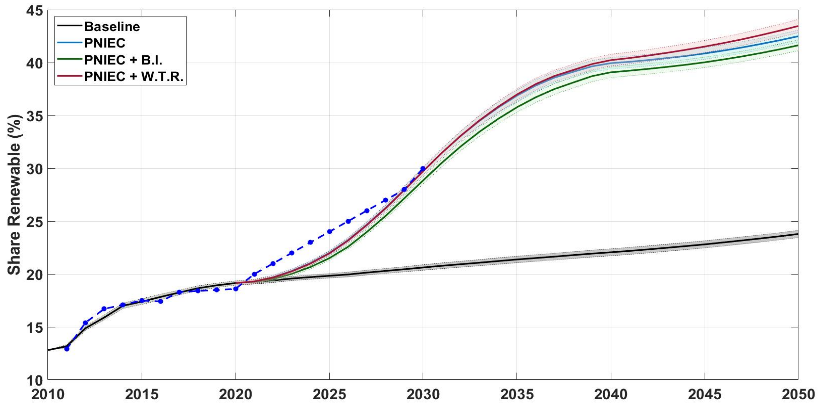
The growth in public debt illustrated in Figure 3c follows diverging paths under each scenario after 2020. Under the baseline it is steady until 2030 and then slightly increases, reaching 3% per year in 2050. The *PNIEC* scenario with and without the introduction of *WTR* reaches almost the same ratio in 2050 ($\sim$ 2%), although the *PNIEC* scenario always remains below the *PNIEC + WTR*. The lower deficits under *WTR* are due to increased public revenue from labour and income taxes that follow a massive increase in the number of employed workers. The addition of a basic income programme is, as expected, costly to the public sector. The increase in tax revenue from higher income and consumption is not enough to offset expenditure in basic income, thus pushing the government deficit-to-GDP ratio beyond 4% after 2045.

Despite underwhelming economic growth – with yearly growth rates around 1% in all three policy scenarios – the social impacts of the simulated policies differ significantly in terms of unemployment rates and income inequality (i.e., Gini index), as shown in Figure 4. The labour market is substantially affected by the *WTR* which reduces unemployment rates (4a) from around 12% in 2020 to $\sim$2.5% in 2050, due to the constant decrease in working hours. However, such a considerable increase in employment is not enough to offset the reduced yearly earnings from working less hours, thus leading to a decrease in the total gross wage bill with respect to the other two policy scenarios. The addition of *BI* reduces unemployment rates by 1% with respect to the *PNIEC* scenario. However, these two policy mixes have similar trends, with unemployment rates stable around 12-13%.

These contrasting impacts respectively of *WTR* and *BI* on unemployment rates are explained by how directly such policies affect employment. While the former directly increases labour demand, as measured

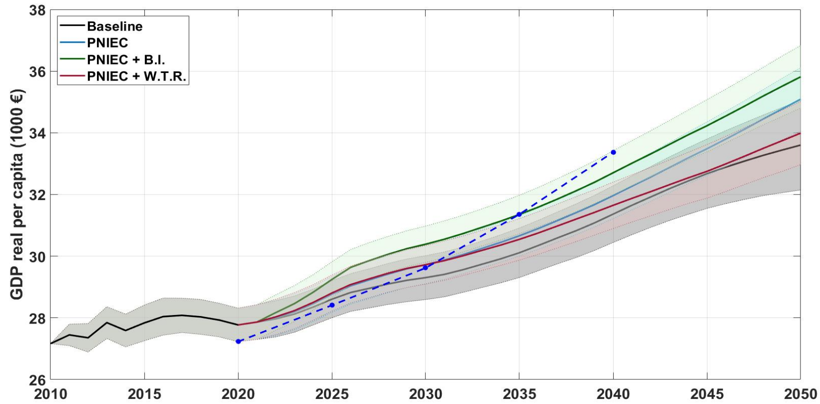



**(a)** Share of renewable energy on electricity.

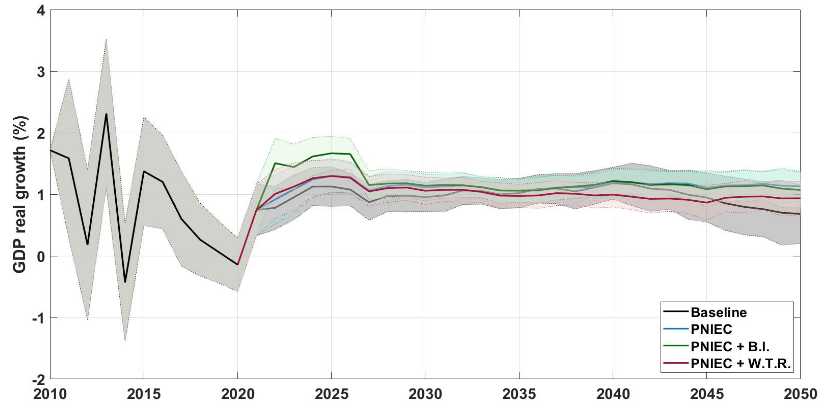



**(b)** Share of total renewable energy.

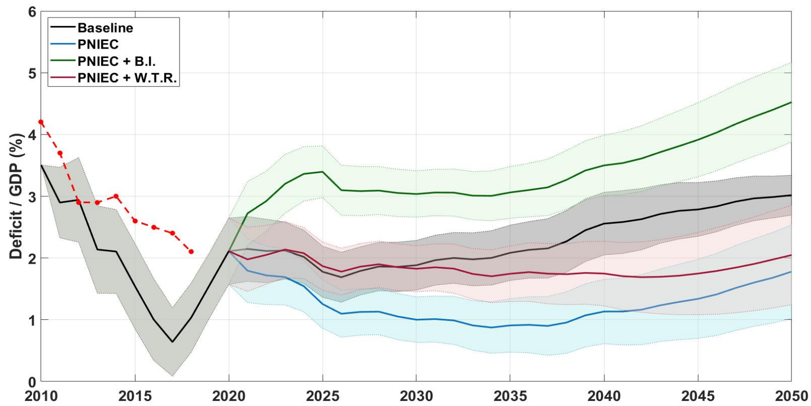
**Figure 2: Share of renewable energy.** Comparison – from 2010 to 2050 – of the share of renewable energy on electricity generation (left) and on final energy use (right) under the baseline (black) and the three policy mixes: *PNIEC* (blue), *PNIEC + Basic Income* (green), and *PNIEC + Working Time Reduction* (red). The navy blue dotted line, until 2030, represents the values projected by the official *PNIEC* plan. The shaded areas around the lines indicate one standard deviation confidence intervals.




**(a)** GDP per capita (base 2010)



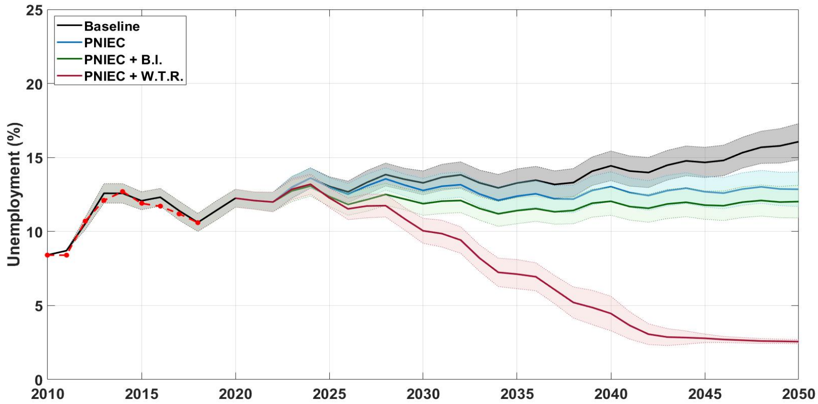

**(b)** GDP growth rate (base 2010)



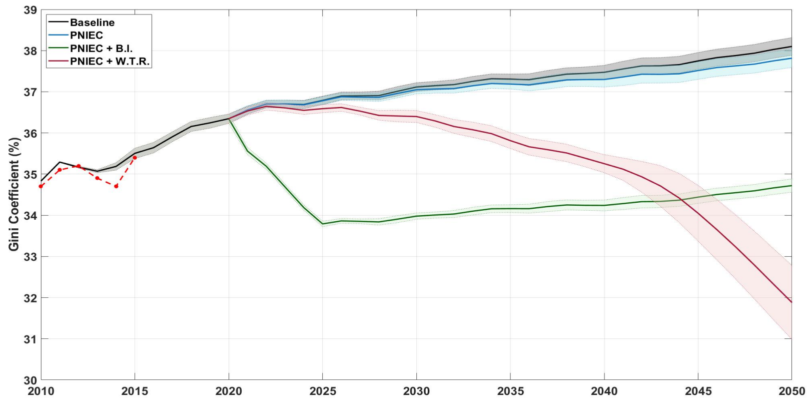

**(c)** Government's deficit-to-GDP ratio

**Figure 3: Economic performance.** Comparison – from 2010 to 2050 – of the GDP per capita (top left) and GDP growth rate (top right), in real terms (base 2010), and the government deficit-to-GDP ratio (bottom) under the three policy scenarios: *PNIEC* (blue), *PNIEC + Basic Income* (green), and *PNIEC + Working Time Reduction* (dark red); and the baseline (black). The dotted navy blue line on the top-left panel indicates the projected GDP per capita in the official *PNIEC* report, while the dotted red line in the bottom panel plots the actual values of the Italian deficit until 2018. The shaded areas around the lines indicate one standard deviation confidence intervals.

by the number of workers required to attain production levels compatible with aggregate demand, the latter is only indirectly related to labour demand through the increase in consumption, mostly of low-skill inactive and unemployed individuals who benefit from the basic income programme. All the policy




**(a)** Total unemployment rate.




**(b)** Gini coefficient.

**Figure 4: Social effects.** Comparison – from 2010 to 2050 – of the total unemployment rate (left) and the Gini coefficient (right) under the three scenarios: *PNIEC* (blue), *PNIEC + Basic Income* (green), and *PNIEC + Working Time Reduction* (red); and the baseline (black). The dotted red lines plot the observed values of unemployment rates and the Gini coefficient until 2018 and 2015, respectively. The shaded areas around the lines indicate one standard deviation confidence intervals.

scenarios, including the *PNIEC* without social policies, project unemployment rates below the baseline. However, these remain substantially high in *PNIEC* and *PNIEC + BI*

The Gini coefficient is presented in panel 4b.[25] The *PNIEC* follows the same increasing trend as the baseline, with growing income inequalities that are reflected in an increase of around 36 to 38 in the Gini coefficient between 2020 and 2050. Both social policies result in a significant reduction in income inequality. The introduction of a *BI* policy has a large and sudden impact during the five years in which the transfer programme is introduced. This initial income distribution is followed by a slow but persistent increasing trend of the Gini coefficient after 2025.

The introduction of *WTR* leads to a persistent and accelerating decrease in income inequality. After a modest initial increase in the Gini after 2020, the *WTR* projects a sharp decrease in the Gini coefficient to 32 in 2050. The acceleration of income distribution under *WTR*, particularly after 2040, is due to the effects of low unemployment rates over labour force participation and wages. Falling unemployment rates increase the number of inactive workers that join the labour force. In turn, the increase in overall employment rates and relative scarcity of workers increases hourly wages which further contributes to improve income distribution.

These simulated scenarios suggest that the beneficial social effects of the energy policies advocated by the official Italian plan (Ministero dello Sviluppo Economico, 2018, p. 4-5) and other proponents of green growth are not automatic and not a necessary consequence of economic growth. Direct social policies are

[25] The Gini of the current study is based on the 13 different heterogeneous agent-groups in our model: low, middle and high-skill workers who are either employed, unemployed, inactive or retired, or capitalists (rentiers). The calculation includes both work, benefits and financial earnings from bonds and equity holdings.

hence desirable to combine environmental targets with more social justice. In fact, our *PNIEC* scenario is characterized by a small reduction in unemployment rates, with respect to the baseline, and increasing income inequality. Job creation and social inclusion are explicitly mentioned as objectives or desirable consequences of the energy transition promoted by the official national plan. Still, it is not clear how these should be achieved. In our projected *PNIEC* scenario not even a very significant expansion in renewable energy investments is enough to outpace the impact that increasing labour productivity has on unemployment, labour force participation and, consequently, aggregate demand. Importantly, despite the massive effort to transform energy production and efficiency, the energy sector constitutes only a small fraction of total national output (about 5% in 2010). Addition of the two social policies illustrates how the joint achievement of social and environmental goals may be either complementary or substitutable. Even though both *BI* and *WTR* improve income distribution, they do so through different channels. The former directly transfers income to low-skill-low-income households and expands aggregate demand while the latter increases employment, though reducing individual yearly earnings. Consequently, as *BI* boosts production and $CO_2$ emissions, *WTR* reduces total energy consumption and emissions due to its moderating effect on aggregate demand.

### 4.3 Technological progress

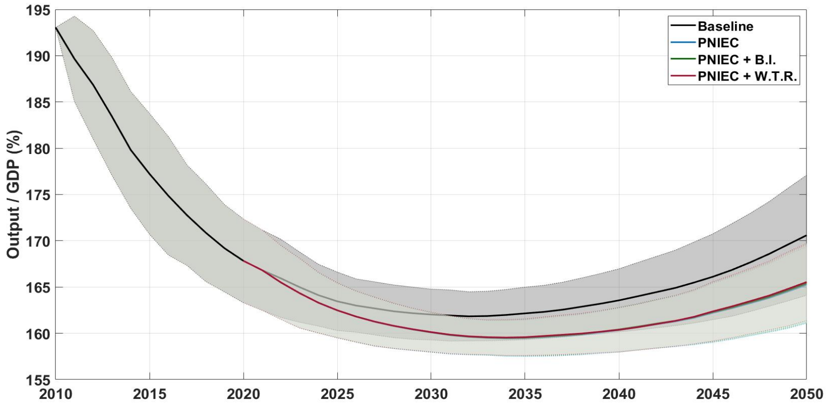
This section briefly presents the three main aggregate technological indicators in the model. Figure 5 plots the simulated values for the output-to-GDP ratio (5a), energy efficiency (5b) and the labour productivity index which is equal to 100 in 2010 (5c). The three panels depict negligible differences between the three policy scenarios although the latter differ from the baseline.

The output-to-GDP ratio measures the amount of intermediate goods needed to produce a unit of GDP. It falls together with the technical coefficients of the input-output matrix and thus roughly expresses the amount of materials and intermediate inputs required to produce a certain level of GDP. The energy intensity measured in 5b is calculated as the ratio of final energy consumption over GDP. Hence, as the output-to-GDP ratio, it is a measure of efficiency in production and should also decrease together with the technical coefficients of the industries that supply energy products.[26] The final technological indicator in 5c measures the amount of output produced by a single worker in one hour.

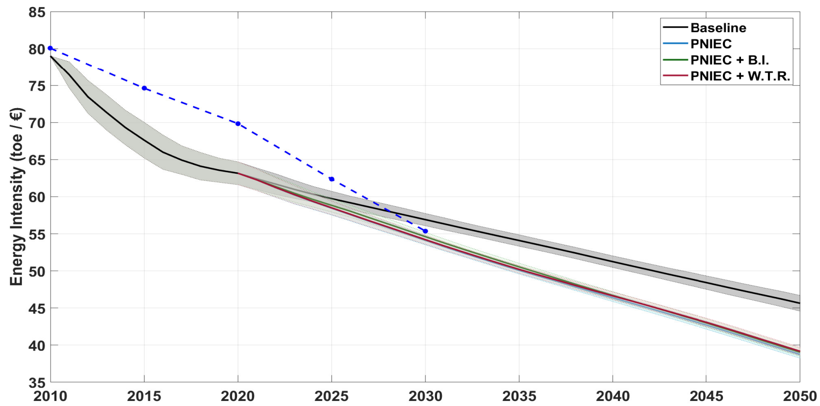
To properly understand the three graphs in figure 5 in light of the endogenous process of technological change described in section 3.1 they should be interpreted together. The identical trend followed by the three policy scenarios is explained by the common energy policies simulated in them. In comparison to the baseline, the introduction of the carbon tax and the gradual switch from coal and liquid to gas in electricity generation and from other energy products to electricity due to the electrification policy all increase the cost of energy as an intermediate input. Our three energy policies thus make it more likely that industries will adopt the intermediate goods-saving and labour-augmenting technology (*b.*) than its labour-saving and intermediate goods-augmenting counterpart (*a.*) whenever they are available. These additional costs explain why our three policy scenarios project lower, more efficient, output-to-GDP and energy intensity indexes while underperforming in terms of labour productivity with respect to the baseline.

Nonetheless, despite the incentives for energy efficiency, we see an inflection in the trend of the output-to-GDP ratio after 2035 in graph 5a. Note that this inflection occurs contemporaneously with the acceleration of the labour productivity index (5c). The initial cost reduction in intermediate goods also increases the relative cost of labour, pushing innovation towards labour-saving technologies. However, the same inflection is not observed in energy intensity. Since it depends on the actual consumption of energy, measured in toe, energy intensity is also affected by the change in energy sources fostered by the policies simulated under the *PNIEC* scenario. Accordingly, the transition towards gas and renewable energy sources, in addition to the reduction of the technical coefficients, also reduces the amount of energy required per unit of GDP produced.

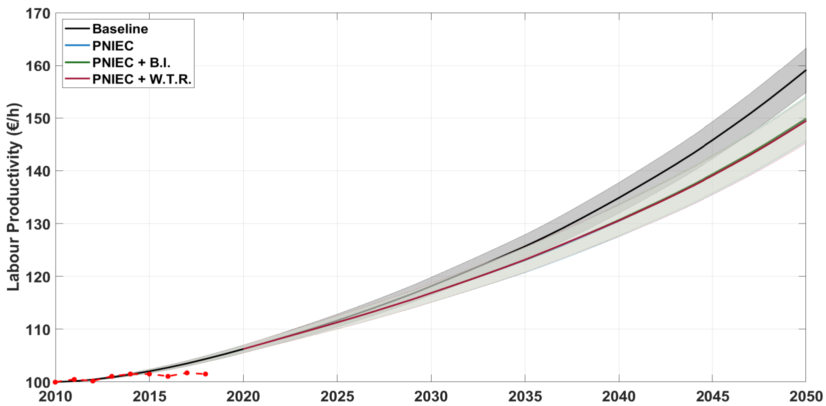
[26]That is, when all other industries that demand energy products adopt technologies that require less energy in its different forms such as electricity or oil to produce a unit of output. In more technical terms, the energy efficiency index falls if the technical coefficients of one or more of the four energy-supplying industries – mining, fossil energy, gas and electricity generation – is reduced. Thus, the coefficients that ought to fall to decrease energy intensity are in the lines of the input-output matrix. However, the choice of technology is performed from the demand side, i.e. industries in the column of the matrix. Therefore, less energy-intensive technologies will be adopted if, and only if, they are less costly than other technologies available, as explained in section 3.1.




**(a)** Output-to-GDP ratio




**(b)** Energy Intensity




**(c)** Labour Productivity

**Figure 5: Economic efficiency.** Comparison – from 2010 to 2050 – of the total output-to-GDP ratio (left), energy efficiency (right) and labour productivity (bottom) under the three scenarios: *PNIEC* (blue), *PNIEC + Basic Income* (green), and *PNIEC + Working Time Reduction* (red); and the baseline (black). The navy blue dotted line, until 2030, represents the values projected by the official *PNIEC* plan. The dotted red line plots the observed values until 2018. The shaded areas around the lines indicate one standard deviation confidence intervals.

## 4.4 Disaggregated results

Some of the detailed results decomposing workers among three skills and production among the NACE industries are presented below. In order to keep the following figures as readable as possible we aggregate the 29 NACE industries into seven macro-sectors.

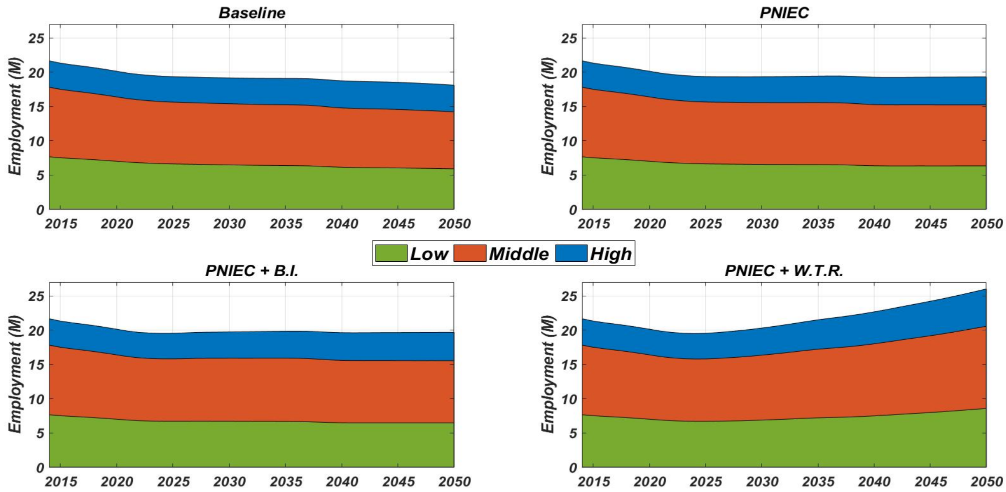



**Figure 6: Employees by skill**. Millions of employed workers from 2010 to 2050 under the four scenarios: baseline (northwest), *PNIEC* (northeast), *PNIEC + BI* (southwest), and *PNIEC + WTR* (southeast). Employees are split between the three skills: low (green), middle (orange), and high (blue).

The composition of total employment, by skill, in the simulated scenarios is presented in figure 6. The three skill levels are defined according to the maximum occupational attainment of the Italian working age population.[27] Below the baseline, there is substantial job destruction with a loss of almost four million jobs between 2010 and 2050. Both *PNIEC* and *PNIEC + BI* present very similar trends, with a stronger decrease in the total number of employed individuals in the first ten simulated years. In spite of the very similar employment patterns in these two scenarios the number of employed workers is slightly larger with the basic income programme. There is also a relative decrease in the share of middle-skill employment during the first 10 simulated years in the four scenarios. This job polarization trend (Goos et al., 2009; Acemoglu and Autor, 2011) seems to be reversed once working time reduction is introduced in the bottom-right panel. Additionally, *WTR* leads to a sharp increase in total employment, from around 22 million in 2010 to almost 26 million in 2050, albeit each working fewer hours.

The structural change promoted by the three policy-mix scenarios is clearer in figure 7 which presents

[27]Low-skill workers are those with lower secondary education or below, middle-skill workers those with secondary or post-secondary, non-tertiary education, and high-skill workers those with tertiary education.

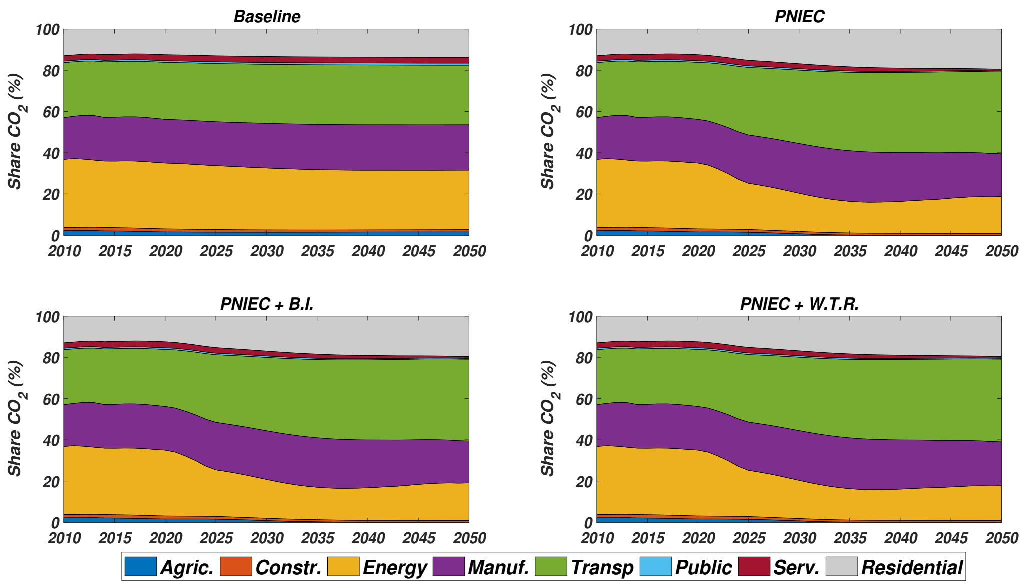



**Figure 7: GHG emission decomposition.** Total $CO_2$ emissions from the seven macro-sectors and the residential sector (households), from 2010 to 2050, in the four scenarios: baseline (northwest), *PNIEC* (northeast), *PNIEC + BI* (southwest), and *PNIEC + WTR* (southeast).

the share of the seven macro-sectors plus the residential sector in total $CO_2$ emissions. The results of the environmental policies simulated to replicate the *PNIEC* in all three policy scenarios are evident in the relative reduction of the energy macro-sector in total CO2 emissions from 2020 onwards, as well as in the lower CO2 emissions from households and services due to higher energy efficiency. Nonetheless, Figure 7 also denotes the limits of the planned environmental policies. The relative, although not absolute, increase in $CO_2$ emissions from manufacturing and transport industries represents the limits of current technological trends in substituting polluting energy products with electricity from renewable sources. These two macro-sectors include the largest use of solid and liquid fuels as well as natural gas. The change in intermediate-inputs and energy-saving technologies required to reach *PNIEC* goals is not enough to promote greater decarbonization of industrial processes and transportation which keep emitting significant quantities of $CO_2$ throughout the whole simulation period.

# 5 Conclusions

Our results support three major conclusions. First there is little evidence that the environmental policies associated with green growth will significantly boost job creation and social cohesion through economic growth. Investments in renewable energy sources and energy efficiency can, to some extent, create jobs and improve income distribution. However, such benefits are more than offset by the negative impacts on employment and distribution of incentives to increase labour productivity and reduce material consumption. These findings suggest the need to couple environmental policies with direct social interventions. Nonetheless, despite their positive effects on income distribution and employment rates, different social policies have their drawbacks that might impede or slow down the achievement of environmental goals.

The two social policies evaluated in the current study promote social equity through different channels. In *PNIEC + BI* the introduction of a large-scale basic income programme is able to temporarily increase GDP growth and marginally reduce unemployment rates with respect to the *PNIEC* policies alone. However, it does so at the expense of renewable energy and $CO_2$ emission reductions as a consequence of greater aggregate demand. The basic income programme further imposes a disproportionate burden in terms of the government's deficit-to-GDP ratio which remains systematically above the 3% limit defined in the Maastricht Treaty.

In contrast to basic income, the inclusion of working time reduction together with *PNIEC* policies actually improves the shares of renewable energy (2) and limits the increase in final energy consumption while reducing deficit-to-GDP ratio, particularly after 2030. The *PNIEC + WTR* policy mix matches environmental targets with social goals. It increases employment and labour force participation which, in turn, improves income distribution. However, it must be noted that individual average income remains significantly below that of the other two policy scenarios. Hence, there are potential limits to such a substantial fall in working hours. Even though simulations indicate an overall improvement in unemployment rates and in the Gini coefficient, workers would have to accept lower income and consumption levels which might foster social unrest.

The main consequence of implementing social policies is that an improvement in environmental performance in terms of $CO_2$ emissions and energy consumption is strictly related to the level of economic activity. In other words, the projected levels of technological change in energy efficiency, electrification, renewable energy production and carbon taxes are not sufficient to promote strong decoupling between energy use and growth. Our simulations suggest that in order to achieve the ambitious goals of 80% reduction in $CO_2$ emissions by 2050 (European Commission, 2018, p. 17) it would be necessary to promote a far-reaching process of structural change, which seems highly unlikely with the capabilities of current technologies.

This trade-off between growth and $CO_2$ emissions limits the policy mixes that are likely to deliver the environmental and social goals of the GND. Policy-makers should be wary about considering the simultaneous introduction of strong environmental and social policies since the latter might offset the effects of the former by increasing demand and consumption. On the other hand, alternative social policies such as working time reduction in our policy scenarios may complement environmental policies through lower demand while improving income distribution.

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