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Environmental impacts of productivity-led working time reduction

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ABSTRACT

This contribution shows that a relevant curtailment of carbon emissions results from *productivity-led working time reduction*, i.e. increases in labour productivity converted into less working time. However, the interaction between working time reduction and GDP can constrain the achievement of emission reductions. To explore these interactions, we apply Eurogreen, a dynamic macro-simulation model, to France and compare three different scenarios: i. Working Time Reduction converts increases in labour productivity into more time affluence; ii. Global Working Time Reduction explores the effects on exports when working time reduction occurs also abroad; iii. Constrained Working Time Reduction additionally examines the impact of a binding fiscal rule. We find that the greater the performance in terms of emission reduction, the smaller the improvement in employment. Moreover, under working time reduction, changes in the sensitivity of wage to productivity growth affect the relationship between distribution and emission. The benefits in emissions reduction are still significant while the labour share increases with respect to the baseline.

1. Introduction

The promise that geoengineering and negative-emission technologies will soon be available feeds the optimism of those who believe that growth in consumption could be sustained despite the current climate and environmental crisis. The green growth paradigm that inspires most of the policy interventions worldwide is based on the same technological confidence. Incentives and investments will trigger the innovations that will eventually decouple economic growth from carbon emissions via increasing efficiency and renewable energy (Jänicke, 2012; Hallegatte et al., 2012). This emphasis on techno-economic solutions has drawn attention away from the harmful social effects of green growth (D'Alessandro et al., 2020) and from the benefits of social innovations (Antal, 2018).

The confutation of innovation-driven decoupling between growth and emissions (Wiedmann et al., 2015; Heun and Brockway, 2019) has led an increasing number of researchers to consider the curtailment of energy demand and production downscale as the cornerstone of a fast low-carbon transition (Alier, 2009; Kallis, 2011). Recent studies analysing the social effects of environmental policies highlight that, not only are social policies needed to compensate for the detrimental effects of green growth incentives on inequality, but they are also necessary to jointly meet social and environmental goals (Baland et al., 2018; Schor and Jorgenson, 2019).

In this paper, we investigate to what extent a social innovation process such as working time reduction may curtail emissions, in the absence of any new environmental policy. To this purpose, we apply a macrosimulation analysis to France and study whether different forms of working time may succeed in meeting environmental targets while improving employment and distribution. The French case is of particular interest for at least two reasons. First, a working time reduction policy was introduced by law at the turn of the year 2000, but with no substantial impact on working time, since the reduction of hours in contracts (35 h) has been mostly compensated by the increase in overtime (Askenazy, 2013). Secondly, despite the policies introduced to decouple green gas emissions from energy use, the measures adopted seems not sufficient to comply with the environmental commitment made in the Paris agreement.[1]

Working time reduction is primarily advanced in the public debate for its potential beneficial effects for employment and work conditions (De Spiegelaere and Piasna, 2017; Messenger, 2018). Indeed, working less has the potential to reduce occupational health problems and to favour a better balance in the allocation between work and free time, so contributing to life satisfaction and happiness of employed (Sparks

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[1] In 2018, the overall share of energy from renewable sources (16,6%) was below the EU27 average (18,9%) and far from the target (23%) set for 2020 (source: Eurostat (2020b)). Moreover, greenhouse gas emissions per capita have shown only a marginal reduction from 7.1 in 2014 to 6.9 tons in 2018 (source: Eurostat (2020a)).

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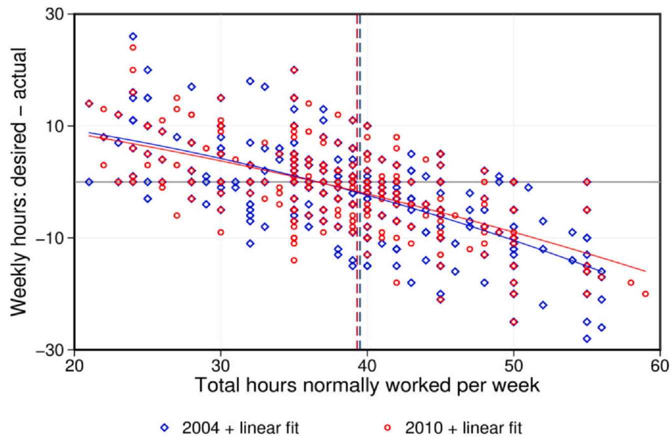


Fig. 1. Willingness to reduce working time. Source: French data from the European Social Survey using waves 2 (2004) and 5 (2010). The *x*-axis plots the reported total hours normally worked per week, including overtime, from employed individuals working between 20 and 60 h per week. The difference (*y*-axis) is calculated using the declared number of hours individuals would like to work subtracted from the same variable used in the *x*-axis. The dashed blue horizontal line at 39.5 represents the actual average hours worked per week including overtime in 2004 and the red one at 39.1 those in 2010. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2001; Hamermesh et al., 2017). For the unemployed and underemployed, working time reduction could represent the opportunity to access a level of income and benefit coverage higher than those provided by present forms of flexible part-time or "marginal" part-time employment (Fagan et al., 2014). Consequently, working time reduction would possibly counteract the increasing inequality in the distribution of work hours (Messenger et al., 2007). Fig. 1 presents a graphical representation of workers willingness to redistribute work hours in France. The scatter plot shows a negative correlation between the actual weekly working hours (in the *x*-axis) and the difference between desired and actual hours worked (in the *y*-axis). On average, those working longer hours would like to reduce their work weeks and those working shorter hours would like to increase them.

Recent academic contributions have placed the reduction of working hours on the forefront among the policies considered capable to reduce environmental pressure whilst improving workers conditions and employment (Fagan et al., 2014; Zwickl et al., 2016; King and van den Bergh, 2017). However, the assessment of the potential impact of working time reduction on emissions mitigation requires a comprehensive understanding of its interactions with other macroeconomic variables. Previous studies argue that this effect depends on a relative decrease in GDP growth resulting from a substitution of private consumption with more free time. (Spangenberg et al., 2002; Schor, 2005; Hayden and Shandra, 2009; Knight et al., 2013; Pullinger, 2014; Fitzgerald et al., 2018). We show that if the increase in labour productivity is converted into more time affluence, keeping constant the annual product per worker, the wage bill declines, thus reducing consumption and income relative to the baseline projection. We term this process *productivity-led working time reduction*.

Nonetheless, such a process would entail further macroeconomic effects that are worth scrutinizing. A wide-scale productivity-led working time reduction would affect employment and prices which, in turn, could lead to non-trivial effects on GDP and production. We first present a theoretical analysis of the impact of working time reduction on labour income under different wage growth assumptions. Secondly, since there is no historical basis to analyze such phenomenon empirically, we adapt Eurogreen, a dynamic macrosimulation model developed in (D'Alessandro et al. (2020), to simulate a productivity-led working time reduction over the period 2014–2050 and to identify feedback loops that mediate the relation between working time and GHG emissions.

Three alternative scenarios are compared to a baseline case to assess the impacts of productivity-led working time reduction under different conditions. The first scenario, Working Time Reduction (**WTR**), considers a single modification to the baseline: labour productivity increases are converted into a proportional change in working time. The second scenario, Global Working Time Reduction (**GWTR**) adds a contraction in exports to mirror a situation in which a similar strategy is adopted by other countries. Lastly, the third scenario, Constrained Working Time Reduction (**CWTR**), adds to the second the automatic adherence to the current European Fiscal Stability Pact by cutting government expenditure whenever the deficit-to-GDP ratio exceeds 3%.

The results show that working time reduction curtails emissions while improving employment conditions. Nonetheless, this environmental benefit is partially offset by an increase in exports due to lower domestic prices, which at the same time strengthen job creation. By contrast, the fall in exports added in the second scenario further reduces environmental impacts, but results in an increasing government deficit-to-GDP ratio. The introduction of a binding fiscal rule improves government balance, but rolls back most of the employment gains of working time reduction.

Our analysis suggests an apparent conflict between socio-economic and environmental goals. However, once distribution consequences are taken into account, this conflict turns out to be less stringent. To clarify these consequences, we add a further working time reduction scenario that keeps hourly wage growth as in the baseline. The increase in labour income fosters economic growth and employment without compromising environmental benefits, and it results in a notable improvement in the labour share with respect to the other scenarios.

The following Section outlines the recent literature on the relation between working time reduction and environmental impact. In Section 3, we present the theoretical backgrounds of the model and define the scenarios. Section 4 presents the simulation results for the relationship between employment and environmental benefits. Section 5 focuses on the distributional impact of working time reduction. Section 6 discusses the main barriers to the joint achievement of social and environmental goals via working time reduction, and concludes.

2. Working time reduction and environmental impacts

Empirical studies over the last two decades have found substantial evidence of a positive correlation between working time and multiple measures of environmental degradation. These studies suggest that reductions in worked hours are related to lower carbon dioxide emissions, energy consumption and ecological footprint in OECD countries and among U.S. states. (Schor, 2005; Rosnick and Weisbrot, 2007; Hayden and Shandra, 2009; Knight et al., 2013; Nässén and Larsson, 2015; Fitzgerald et al., 2018). Two mechanisms have been proposed to explain this evidence: 1) a *composition effect* that refers to a shift in consumption patterns towards less energy-intensive goods and services following greater time availability; 2) a *scale effect* due to the decline in the rate of growth of income and consumption that drives a reduction in resource use and environmental pressure.

Studies investigating the *composition effect* have provided mixed evidence. Even though consumers might reduce demand for speed and convenience – for instance substituting public for individual transportation – they could also increase their expenditure on tourism and air travels, as suggested by Schor (2005). Another possible drawback of an increased time affluence is identified by Jalas (2002) who notes that at least some activities that are substituted after working time reduction could be less eco-efficient (e.g., preparing meals at home vs eating in restaurants).

The explanation of the positive environmental impact of working time reduction based on the *scale effect* achieved a larger scientific consensus (Pullinger, 2014). Knight et al. (2013) find evidence of a scale, but not of a composition effect, using data for emissions and ecological footprints in OECD coutries. However, Shao and Rodríguez-Labajos (2016) find that the correlation between worked hours and CO_2 emissions turned from positive to negative after the year 2000, and find no significant correlations for developing countries. Furthermore, Shao and Shen (2017) find a negative correlation between working hours and carbon emissions among high-level working time observations, and a positive one in low- and mid-level working time observations by using panel threshold regressions.[2]

None of these empirical studies estimate causal relation from working time reduction to consumption or GDP. The observed reduction in working hours might be interpreted as a cause or as a consequence of stagnant GDP. On the other hand, theoretical contributions do not settle the matter concerning the direction of causality between working time reduction and degrowth. Most authors seem to agree that a fall in working hours – and the reduction in income and consumption that would follow – might be a possible cause of degrowth (Hayden and Shandra, 2009; Jackson and Victor, 2011; Knight et al., 2013). However, working time reduction is also advanced as a strategy to cope with unemployment in a post-growth society (Jackson and Victor, 2011, p.101). In this study, we contribute to this literature investigating the causal link between working time reduction and GHG emissions by clarifying the feedback loops that condition the effectiveness of working time reduction.

3. Methods

The Eurogreen model describes a dynamic demand-led economy that follows the approach of ecological macroeconomics based on a combination of post-Keynesian theory and ecological economics (see, e.g., Victor and Jackson, 2015; Rezai and Stagl, 2016; Hardt and O'Neill, 2017). The Eurogreen model provides a detailed representation of the welfare system and of the dynamics of income sources allocated to distinct groups of agents depending on their skill, age and working status. The full documentation of the model is available in the Supplementary Information of (D'Alessandro et al., 2020).

The model is composed of thirteen groups of agents and ten industries. Households are grouped into three skill levels – low, middle and high – and among four occupational status (employed, unemployed, inactive and retired) plus capitalists (0.1% of the population) that receive only financial income. The ten industries demand domestic and foreign intermediate goods, and hire workers to meet their final demand. Inter-industry relations are represented by the input-output matrix.[3]

The model assumes that technical progress increases labour productivity and/or energy efficiency. In each industry, the availability of labour-saving (energy-saving) technologies positively depends on the difference between the growth rates of labour and energy (energy and labour) costs.[4] Moreover, energy-saving innovations affect the technical coefficients of the two energy supplying industries: fossil fuel and electricity & gas. These coefficients decrease whenever any industry implement new energy-saving technologies.

Before introducing the scenarios, it is worth presenting a simplified version of the labour market modelled in Eurogreen that clarifies the main forces at work that mediate the impact of productivity-led working time reduction.[5] For the sake of the argument, let us assume that there is only one type of worker and a single industry. The gross wage bill (B) is given by

$$B = whL = wH, \tag{1}$$

where w is the hourly wage, h are the total annual hours per worker, L is the employment, and H is the total amount of working hours. Since we want to explore the change in time of B to evaluate the presence of a scale effect, it is convenient to rewrite this equation in terms of growth rates g_i for $i = B, w, h, L, H$. Thus,

$$g_B = g_w + g_h + g_L = g_w + g_H. \tag{2}$$

Labour demand is given by

$$L = \frac{y}{\lambda h}, \tag{3}$$

where y is the output and λ the labour productivity. We can rewrite this equation in terms of growth rates, that is

$$g_L = g_y - g_h - g_\lambda \Rightarrow g_H = g_L + g_h = g_y - g_\lambda. \tag{4}$$

Eq. (4) captures the well known relationship between employment (expressed in total hours H), GDP and labour productivity. A reduction in working hours makes employment more sensitive to economic growth. If working hours are fixed, as in the baseline scenario below, the growth rate of employment is given by the difference between the growth rates of GDP and labour productivity. By contrast, if λh is constant, as in the three alternative scenarios, the growth rate of employment equals the growth rate of GDP.

The growth rate of wages depends on the growth rate of labour productivity g_λ and employment (g_L), that is

$$g_w = \omega_\lambda g_\lambda + \omega_L g_L, \tag{5}$$

where $\omega_\lambda \in [0,1)$ and $\omega_L \in [0,1)$ reflect the sensitivity of hourly wage to productivity and employment growth, respectively.

From Eqs. (4) and (5), it holds that,

$$g_B = (1 + \omega_L)g_y - (1 + \omega_L - \omega_\lambda)g_\lambda - \omega_L g_h. \tag{6}$$

From Eq. (6), it is straightforward to highlight the impact of WTR on the gross wage bill. If working time does not change, the last term of Eq. (6) is zero. Otherwise, productivity-led working time reduction means that $g_h = \ - g_\lambda$. Thus it holds that,

$$g_B^{BASE} = (1 + \omega_L)g_y - (1 + \omega_L - \omega_\lambda)g_\lambda, \tag{7}$$

$$g_B^{WTR} = (1 + \omega_L)g_y - (1 - \omega_\lambda)g_\lambda. \tag{8}$$

Table 1 compares the resulting growth rates of the gross wage bill in the Baseline (BASE) and in the productivity-led working time reduction (WTR) according to a number of assumption on the sensitivity of hourly wages to labour productivity and employment. Although, in Eurogreen, GDP growth is endogenous, we present the results assuming that $g_y = 0$ (left-hand side of the Table) and that $g_y = g_\lambda > 0$ (right-hand side).

Note that productivity-led working time reduction does not directly increase employment, but would only prevent its reduction due to labour productivity increases. When $g_y = 0$, any increase in productivity generates a reduction in working hours that keeps unchanged the level of employment. Thus, the annual product per worker is constant (i.e. $g_h + g_\lambda = 0$). Without economic growth, any increase in labour productivity brings about a reduction of the gross wage bill, inducing a reduction in disposable income and private consumption (i.e. scale effect). However, the size of this change depends on the sensitivity of wage to labour productivity. Interestingly, the reduction of the gross wage bill in the Baseline is greater or equal to that in WTR. This is due to the fact that the decrease in employment tends to lower hourly wage, while this effect is absent in WTR.

[2] However, it is unclear if these results can be interpreted as a scale effect since the regressions in Shao and Rodríguez-Labajos (2016, p.232) control for time period dummies and the panel threshold regressions in Shao and Shen (2017, p.326) control for GDP per capita.

[3] The ten aggregated industries considered in the input-output matrix of Eurogreen are: agriculture, mining, manufacturing, fossil fuels, electricity & gas, construction, services, finance, public, and other.

[4] This incentive affects the threshold of a random process at the basis of availability of different technologies.

[5] For a full documentation of the labour market module see Supplementary Information in D'Alessandro et al. (2020) pp. 22–25.

Table 1
Taxonomy of resulting changes in the gross wage bill growth rate (g_B).

Condition	$g_y = 0$		$g_y = g_\lambda$	
	BASE	WTR	BASE	WTR
$\omega_\lambda = 0 \quad \omega_L = 0$	$-g_\lambda$	$-g_\lambda$	0	0
$\omega_\lambda = 0 \quad \omega_L > 0$	$-(1 + \omega_L)g_\lambda$	$-g_\lambda$	0	$\omega_L g_\lambda$
$\omega_\lambda > 0 \quad \omega_L = 0$	$-(1 - \omega_\lambda)g_\lambda$	$-(1 - \omega_\lambda)g_\lambda$	$\omega_\lambda g_\lambda$	$\omega_\lambda g_\lambda$
$\omega_\lambda > 0 \quad \omega_L > 0$	$-(1 + \omega_L - \omega_\lambda)g_\lambda$	$-(1 - \omega_\lambda)g_\lambda$	$\omega_\lambda g_\lambda$	$(\omega_L + \omega_\lambda)g_\lambda$

When $g_y = g_\lambda > 0$, employment is constant in the Baseline while it increases in WTR. Thus, on the one hand, the gross wage bill increases in the Baseline only if the positive effects of productivity growth on wage is considered ($\omega_\lambda > 0$). On the other hand, working time reduction allows for the increase in employment that, in turn, can further increase hourly wages.

The growth rate of the gross wage bill is also tied to a change in distribution and in particular in the labour share. In this simplified version of the model, the labour share (LS) can be defined as the ratio between the gross wage bill and the GDP, i.e. $LS = B/y$ and $g_{LS} = g_B - g_y$). Indeed, if $g_y = 0$ the growth rate of the labour share is equal to the growth rates presented in the left/hand side of Table 1. In other words, it is negative in all cases, but WTR can mitigate this effect. Instead, if $g_y = g_\lambda$, given that $\omega_\lambda \in [0, 1)$, the labour share declines in all cases but the last one with WTR. If $(\omega_L + \omega_\lambda) > 1$ the effect on hourly wages from productivity increase and employment can more than compensate the direct effect of labour productivity.

This argument is a logical exercise that assumes exogenous GDP growth. However, in the Eurogreen model and in the scenarios here considered, GDP endogenously depends on the wage bill, through its impact on private consumption, but also on the other components of the final demand: government expenditure, investments and net exports. Thus, variations in prices, profits, the number of pensioners, unemployed and inactive individuals receiving public benefits also affect GDP. Our scenario analysis attempts to grasp the overall impact of these interactions and feedback loops on GDP, unemployment, emissions and public balance and income distribution.

3.1. Scenarios

To highlight the social and environmental effects of productivity-led working time reduction, we compare the baseline with three alternative scenarios. Our simulations encompass the period 2014–2050 and scenarios differ from the baseline after 2020.

In the **Baseline** scenario, working hours are fixed by industry and hourly wages increase with labour productivity, (i.e. $0 < \omega_\lambda < 1$). Hence, the annual product per worker (λh) increases at the same rate of labour productivity.

In the *Working Time Reduction* (**WTR**) scenario, labour productivity gains do not increase hourly wages (i.e. $\omega_\lambda = 0$) and, instead, they are converted into less working hours per employee. This reduction is proportional to the variation of industry-specific labour productivity. However, hourly wages are not constant since they remain an increasing function of employment ($\omega_L > 0$).

The *Global Working Time Reduction* (**GWTR**) scenario adds to **WTR** an exogenous *export reduction* that mimics the introduction of working time in other countries, by assuming that export growth equals the lagged growth rates of domestic imports, in each industry. The underlying assumption in **GWTR** is that France's trade partners implement an identical reduction in working time and, thus, cut their imports from France at the same rate of French imports, thus resulting in a reduction of French export. This scenario allows us to assess to what extent the effectiveness of working time reduction depends on the trade balance. By introducing this scenario, we are able to assess how much of the difference in GHG emissions between **WTR** and **GWTR** is explained by the increase in exports that follows the change in working time.

The *Constrained Working Time Reduction* (**CWTR**) scenario considers a binding deficit rule. Given the current architecture of the budgetary limits for EU member states (European Commission, 2017), upper bounds to governments' deficit-to-GDP ratios would be particularly stringent in the absence of growth. Under this condition, the fiscal rule can produce an additional reduction of public expenditures that fosters a reduction of GDP growth and employment. As a results, the capacity of job creation of working time reduction could be very limited. This scenario cuts government's final consumption by 1% if the simulated deficit-to-GDP ratio on the previous year exceeded 3% and maintains a 0.5% yearly increase otherwise.

In these three alternative scenarios we assume that $\omega_\lambda = 0$. That is, workers accept to trade all the increase in potential income from productivity for free time, keeping the annual product per worker constant (Fitzgerald et al., 2018). Although this case represents an extreme implementation of working time reduction, the literature already clarifies that this should lead to a high scale effect (Spangenberg et al., 2002; Pullinger, 2014). Note that, according to Table 1, both in the case of zero economic growth or when $g_y = g_\lambda$ the effect on gross wage bill and on the labour share is not worst than that in the Baseline. However, given the several feedback loops considered in Eurogreen, in Section 5, we explore the distributive impact of productivity-led working time reduction comparing the **WTR** scenario with an additional scenario where $\omega_\lambda > 0$ and equal to the value of the Baseline, i.e. the *Working Time Reduction + wage* (**WTR + wage**) scenario.

4. Scale effect assessment

The main simulation results are presented in Fig. 2. It plots the dynamics of the French economy under the baseline and the three alternative scenarios from 2014 to 2050. The graphs report the means and 95% confidence intervals of 200 simulations for each scenario. We perform multiple simulations to account for variations in endogenous technical progress which depends on the availability of randomly extracted technologies at each simulated period.

The economy average reduction in weekly hours is approximately the same in the three alternative scenarios and fall from about 32 in 2014 to about 23 hours in 2050.[6] The fall in hours worked is very similar in our three alternative scenarios because total labour costs do not diverge enough across them to bias technological progress towards more labour-saving innovations. Nevertheless, the scenarios show different patterns in terms of environmental and economic performances.

Panel 2a summarizes the impact of working time reduction on unemployment. The **WTR** scenario shows a significant reduction of unemployment rates which drastically drop from about 10% in 2020 to about 4% in 2050. The **GWTR** scenario results in higher unemployment rates with respect to **WTR**, albeit still well below the **Baseline** projections (around 6.5% against 12% in 2050, respectively). Furthermore, **CWTR** undermines the employment improvements generated by productivity-led working time reduction, leading to an unemployment rate (~10%) slightly below that of the **Baseline**.

The comparison between Panels 2a and 2b shows that the **Baseline** results in the highest GDP growth and the highest unemployment rate.[7] The remarkable decrease in unemployment rate, in **WTR**, is due to the combination of reduced work hours with increasing aggregate demand and output. Indeed, it is the higher GDP growth in the **WTR**, relative to

[6] The initial value of 32 hours seems low. This is due to the fact that our model does not distinguish between full and part-time work. Therefore, hours worked per week are actually an average across all workers in the economy, including those in part-time jobs.

[7] In the baseline, the annual GDP grows at fairly constant rates of about 1%, in line with the forecasts of the *E.U. Reference Scenario 2016* (Capros et al., 2016).

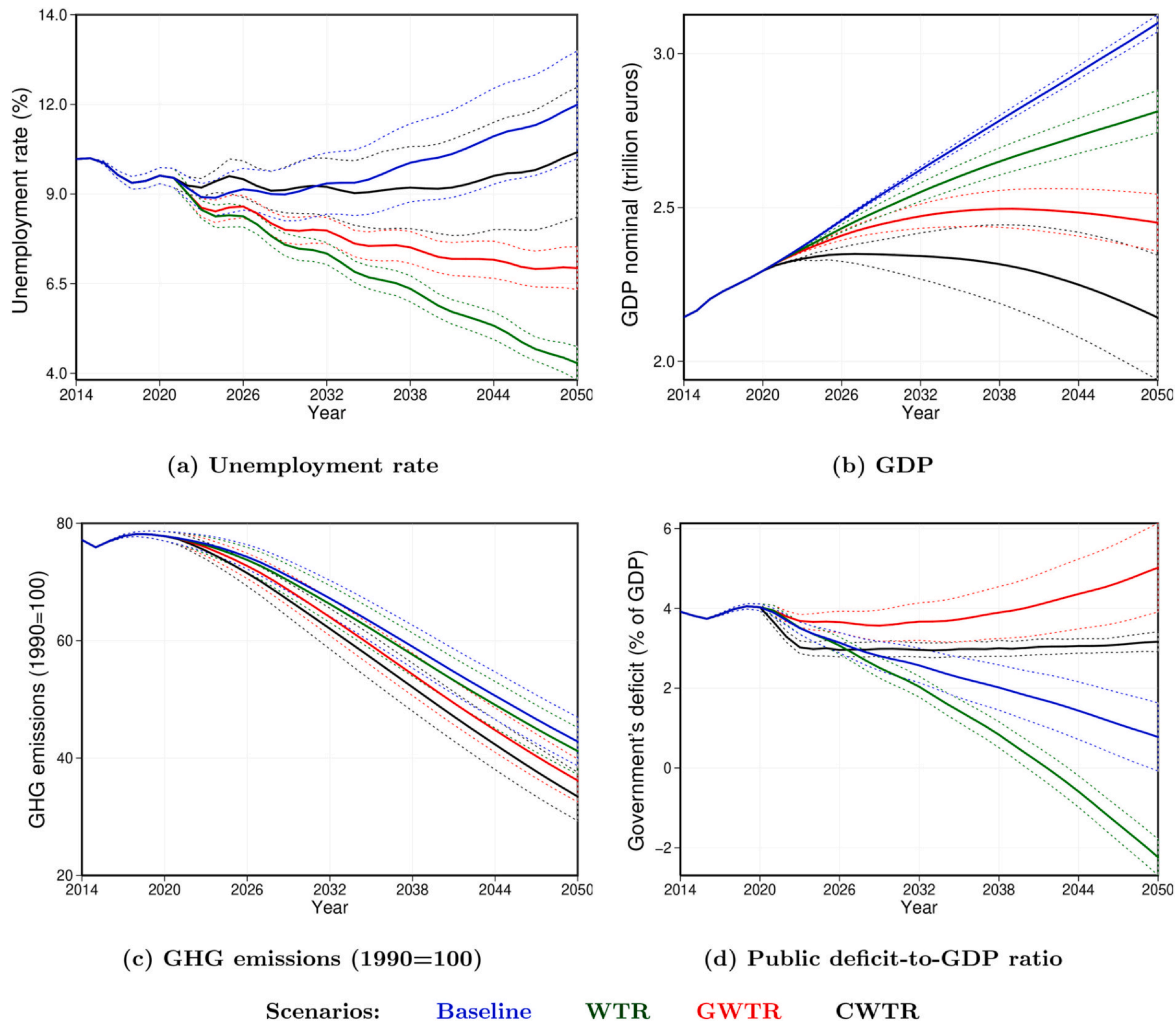


Fig. 2. Main results. Each graph plots the means (solid lines) and 95% confidence intervals (dotted lines) of 200 simulations for each scenario.

GWTR and **CWTR**, that ensures the best performance in terms of unemployment. In other words, the success of working time reduction in curbing unemployment does depend on GDP growth. Nonetheless, Panel 2b confirms the presence of a scale effect since the fall in the gross wage bill induces a lower GDP growth in all the alternative scenarios with respect to the baseline.

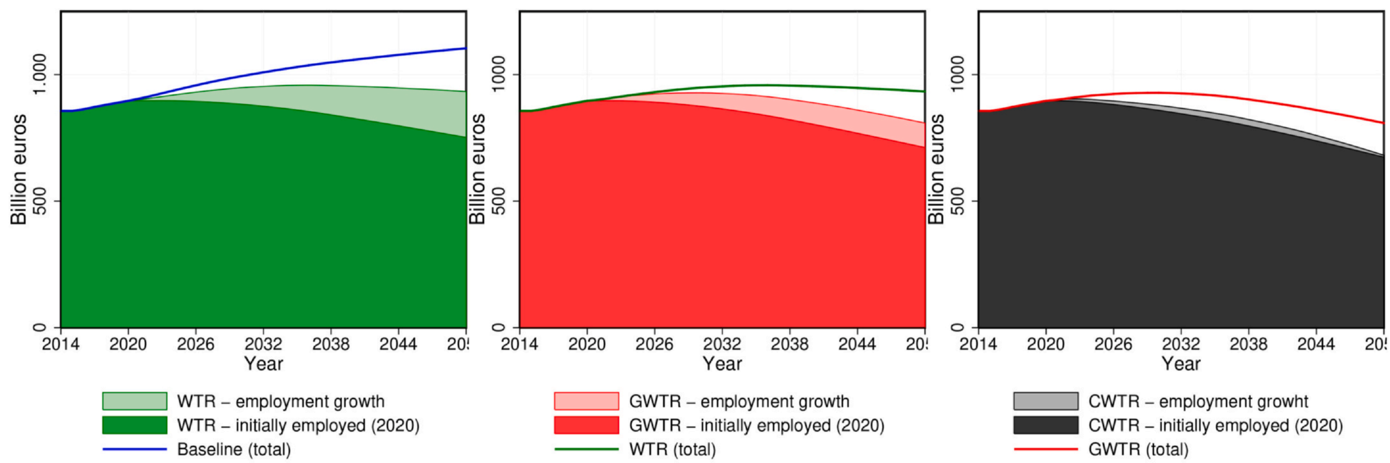
The reductions in total greenhouse gas emissions, measured in *Mtoe* of CO_2 equivalents and plotted as a percentage of their level in 1990, are shown in Panel 2c. The projected trends of efficiency gains from new technologies and expansion in renewable energy in the baseline scenario account for most of the GHG reductions, reaching on average about 70% and 44% of the 1990 level in 2030 and 2050, respectively. Yet, these numbers are above the 60% target of the EU climate action 2030 and remarkably far from the recently announced net zero-emission target in 2050 (European Commission, 2018). The reductions in emissions in the remaining three scenarios closely reflect their respective GDP patterns. By 2050 the reduction in emissions with respect to the **Baseline** is of about 4%, 16% and 22% in **WTR**, **GWTR** and **CWTR**, respectively. As a term of comparison, consider that the baseline scenario of the *National Low Carbon Strategy Project* of the French Government projects 15 MtCO2 of negative emissions per year from carbon capture and storage technologies (Ministere de la Transition Ecologique et Solidaire, 2020). The reductions in our scenarios results in almost 0.6 (**WTR**), 2.5 (**GWTR**) and 3.5 times (**CWTR**) this magnitude.

The path of deficit-to-GDP ratio is presented in Panel 2d. The baseline trend declines from an initial 4% to less than 1% at the end of the simulation period. The picture drastically changes in the alternative scenarios. Public deficit trend downwards under **WTR**, reaching less than −2% in 2050. Under **GWTR**, instead, it grows above the initial 4%, reaching about the 5% in 2050. Since the reduction in exports does not affect public expenditure, this divergence with respect to **WTR** must be attributed to the fall in GDP and to the contraction of government tax revenues. In **CWTR**, adding the binding fiscal rule to **GWTR** maintains the deficit-to-GDP ratio close to 3%.

4.1. Gross wage bill

Fig. 3 shows the variations of the labour income in terms of gross wage bill. The left Panel (3a) compares the **Baseline** (blue line) with **WTR**. The latter is split between the labour income that corresponds to the number of employed workers when **WTR** is introduced in 2020 (dark green) and that of employees hired successively (light green). Overall, **WTR** does decrease total labour income, yet the consequent consumption reduction is partially offset by the increase in employed individuals.

Panel (3b) shows the comparison between **WTR** (green line) and the decomposition of labour income of the **GWTR** (red and light red). The export contraction further reduces both the total gross wage bill and the job creation potential of productivity-led working time reduction. The



(a) WTR (b) GWTR (c) CWTR

Fig. 3. Gross labour income decomposition. Each of the three graphs compares the gross wage bill of two scenarios. The labour income of the compared scenario is further split between the total wages of the number of workers employed in year 2020 (dark green, dark red and dark gray) and those of workers hired after the introduction of reduced working time (light green, light red, light gray). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

total labour income and the creation of new jobs fall even further once the binding fiscal rule is introduced (see right panel, 3c).

Overall, all three scenarios that consider a reduction in working time present lower unemployment rates and GHG emissions with respect to the Baseline. Nonetheless, our results highlight a trade-off between the scale of the improvements in employment and emissions. The contraction of consumption, production and emissions that follow lower yearly wages of employed workers is partially offset by the increased disposable income of formerly unemployed and inactive individuals hired thanks to the working time reduction process. The scale of this compensation effect depends mainly on two factors: *i.* the contraction in gross labour income promoted by working time reduction, and *ii.* the increase in the number of employees that depends on the pace of economic growth. Even though GDP growth rates are lower in **WTR** than in the baseline, they remain positive until the end of the simulation period. When GDP growth becomes negative, as in **GWTR** and **CWTR**, the portion of the wage bill from employment growth falls. Still, the additional reductions of growth and production in the last two scenarios also lead to larger emissions reductions.

4.2. GDP composition

Fig. 4 plots the evolution of aggregate demand components as a percentage of their baseline values. The main distinctive behaviour observed in **WTR** is the expansion of net exports. In **GWTR**, the curtailment of exports induces a stronger reduction in private consumption and investments. In the **CWTR** scenario, the combination of a binding fiscal rule with decreasing GDP brings about a sharp contraction in public expenditure. Thus, the expected emissions reduction due to the scale effect of **WTR** might be offset by an expansion in exports due to the relative decline in domestic demand and prices.

4.3. Public budget balance

Fig. 5 shows the scatter-plot of public revenues (*x-axis*) against expenditures (*y-axis*). Values above the 45° line represent a deficit. Under the baseline, we observe a continued increase in both revenue and expenditure associated to a low but positive deficit until 2050. Under **WTR** and **GWTR**, the public expenditure stagnates until 2030 and it slightly declines afterwards. However, revenues follow diverging paths, with an expansion in **WTR** and a contraction in **GWTR**. The divergent paths in the deficit-to-GDP ratio (see 2d) is determined by the variations in revenue and GDP, instead of expenditure.

The projected behaviour of the government's budget radically changes in **CWTR**. To match the fall in revenue and maintain the deficit-to-GDP ratio below 3%, government's expenditure falls in nominal terms reverting back to their initial values by the end of the simulation period. Such a strong contraction of public expenditure, also seen in Fig. 4, explains why the GDP growth rate turns negative in **CWTR** before 2030 whereas in **GWTR** they remain positive at least until 2040. This result makes it clear that rigid fiscal rules may cancel out the employment gains from working time reduction, particularly if GDP is decreasing. In that case, additional sources of public revenue such as wealth and carbon taxes might be necessary to maintain the welfare system while respecting current deficit rules.

5. Distributional impacts

This section takes a closer look into income distribution. It compares the **Baseline** with **WTR** and a further WTR scenario (WTR + wages) in which hourly wages positively respond to increases in labour productivity.[8]

The two top-row panels in Fig. 6 plot two different indicators of income distribution: the labour share (6a) and the Gini coefficient (6b).[9] The labour share, in Panel 6a, follows a decreasing trend in the **Baseline** and falls even further in **WTR**. This difference is due to the reduction of the gross wage bill, as seen in Fig. 3, and subsequent sluggish GDP growth. As argued in Table 1, this circumstance is explained by the fact that in the absence of GDP growth labour income would increase more in **WTR** than in the **Baseline** ($-g_\lambda > -(1+\omega_L-\omega_\lambda)g_\lambda$[10]). In other words, the difference in GDP growth rates explains the relative low decline of labour share in the **Baseline**.[11] The combination of increasing employment and hourly

[8] In terms of the formalization developed in the Methods Section, ω_λ takes the same value than that of the Baseline.

[9] The Gini coefficient is calculated based on the income of the 13 different groups of individuals modelled in Eurogreen. The first 12 groups are low, middle and high-skill workers that are either employed, unemployed, inactive (out of the labour force) and retired. The final group is reserved to capitalists or rentiers, a fixed 0.1% of the population, whose income depends exclusively on dividends and financial assets.

[10] Assuming that $\omega_\lambda > \omega_L$ as in our simulations

[11] For the same reason, the level of profits between **WTR** and **Baseline** does

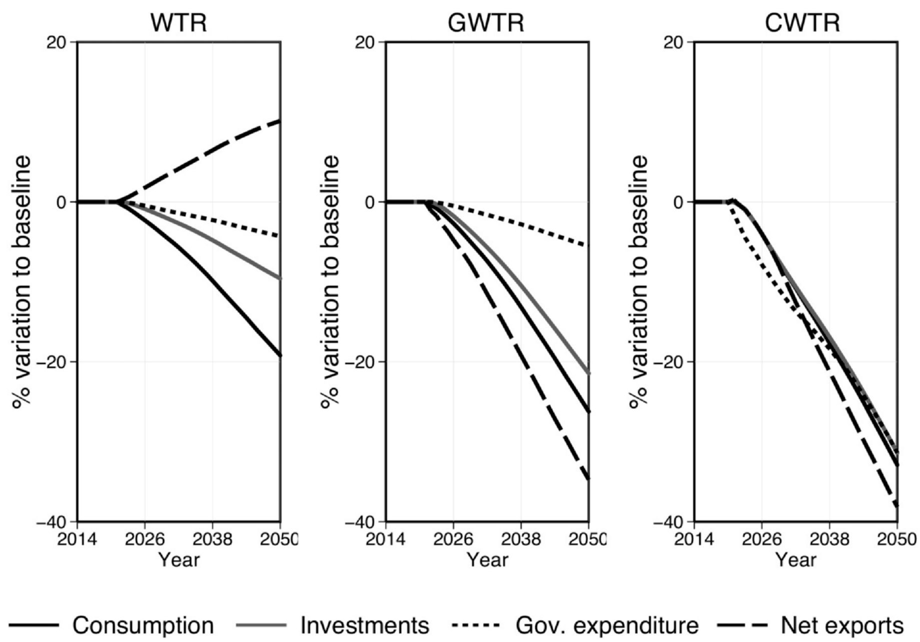


Fig. 4. GDP composition. Comparison between the evolution of private consumption, investments, government expenditures and net exports, in WTR, GWTR and CWTR, as a percetage of the baseline value of these components.

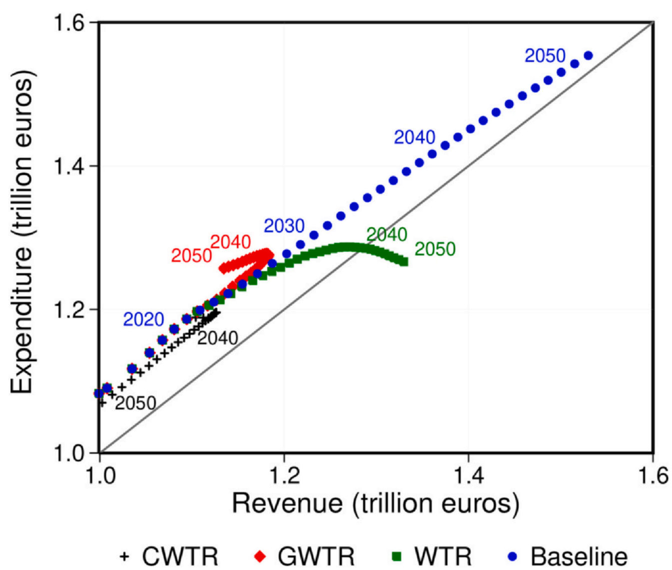


Fig. 5. Government's revenue and expenditure. Simulated government's revenue and expenditure are plotted in the *x* and *y-axis*, respectively. Values above (below) the black 45° line indicate a deficit (surplus).

wages, which results in slightly increasing annual wages, in **WTR + wages** is able to revert the deterioration of the labour share observed in the **Baseline**.

The Gini coefficient (6b) shows a different picture. Income distribution improves the most in **WTR + wages** and worsens in the **Baseline**, but it significantly improves also in **WTR**. This is explained by the notable increase in the number of individuals employed in WTR (6d). Thus, despite the loss of labour income in **WTR**, the absorption of individuals previously unemployed and inactive is still able to improve the overall income distribution. This is evident in panel 6d. It shows how the reduction in working hours results in a qualitative change in employment dynamics with sizable expansion in the number of employed individuals. The role of working time reduction is further highlighted by the similar employment numbers in **WTR** and **WTR + wages.**[12] The additional labour demand in the latter corresponds to the indirect effects of a higher aggregate demand from increasing wages.

The bottom-left panel plots greenhouse gas emissions (6c 1990 = 100). Perhaps surprisingly the reduction in emissions observed in **WTR + wages** is almost exactly the same achieved in **WTR** at the end of the simulation. To better interpret this result we resort, once again, to the behaviour of the different components of aggregate demand.

Fig. 7 plots the aggregate demand components of the new **WTR + wages** scenario as a percentage of those in the **Baseline** (left) and in **WTR** (Right).[13] First, the variation of all GDP components with respect to the baseline is much milder in **WTR + wages** than in the other three scenarios. The reduction in greenhouse gas emissions from Fig. 6c is due to the contractions in private consumption and investments which more than compensate for the modest expansion in net exports and government expenditure, both smaller in scale than consumption and investments.

The right panel of Fig. 7 shows the effects of growing hourly wages. Its combination with higher employment boosts private consumption and aggregate demand, with respect to **WTR**. The increase in aggregate demand in turn accelerates investments and allows government expenditure to grow. However, higher prices follow the increasing unit labour costs, curbing exports.

(*footnote continued*)
not change significantly. Even though, the profit share is higher in **WTR**, with respect to the **Baseline**, total GDP is lower. Hence, total profits are roughly the same in these two scenarios. Moreover, the increase in profits mainly tends to reduce firm's debt, and the increase in consumption out of wealth, especially for capitalists, does not affect the macro-dynamics.

[12] Total reduction in working hours are comparable. By 2050, the economy average of weekly working hours (labour productivity) are marginally lower (higher) in **WTR + wage** (22.61) than in **WTR** (22.97), **GWTR** (23.14) and **CWTR** (23.42).

[13] Note that the left panel is directly comparable with the graphs in Fig. 4 while the right panel enables us to isolate the effects of increasing hourly wages with working time reduction.

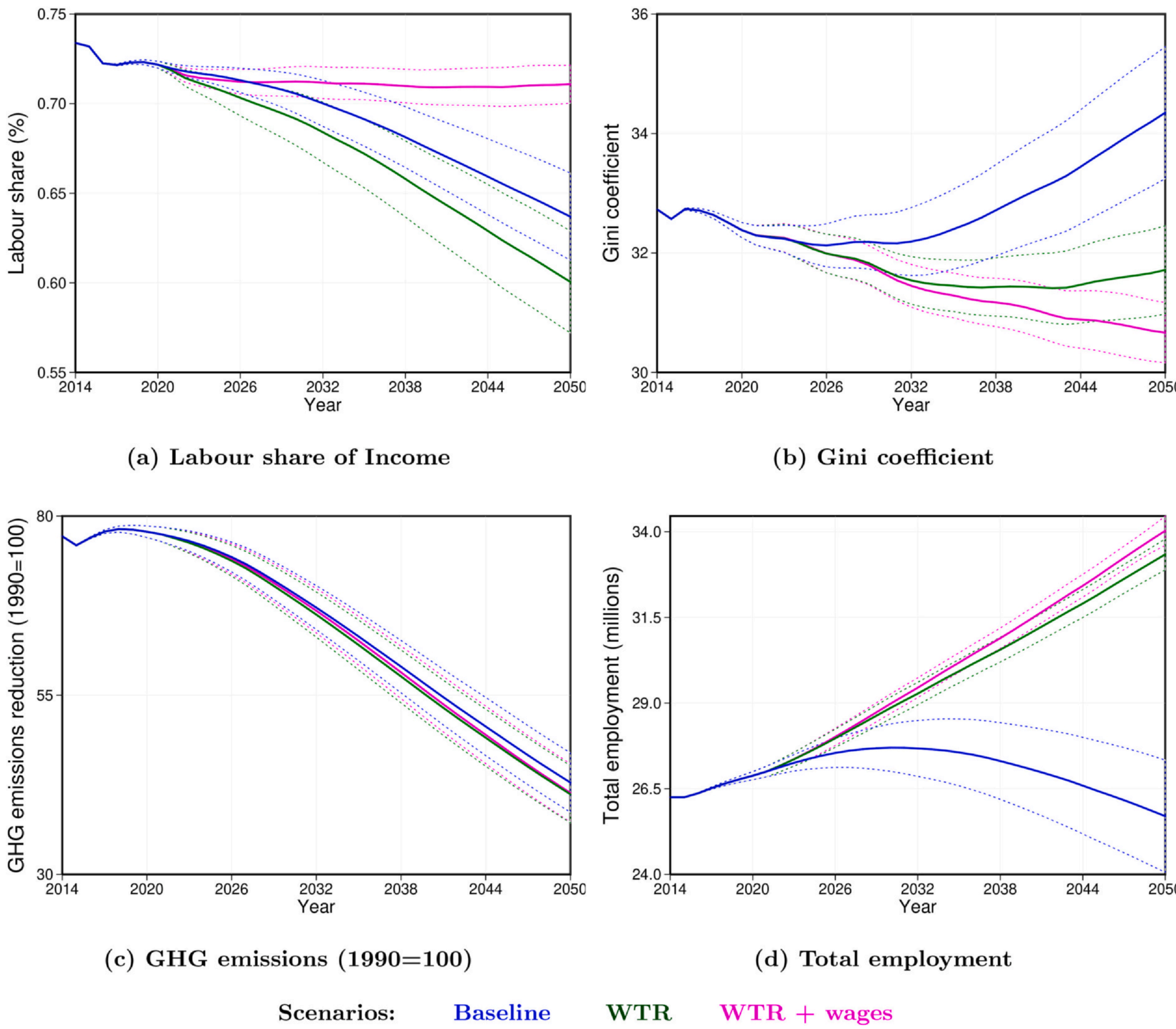


Fig. 6. Income distribution in WTR with and without wage growth. Each graph plots the means (solid lines) and 95% confidence intervals (dotted lines) of 200 simulations for each scenario.

Still, these variations do not fully explain how emissions in **WTR + wages** match those of **WTR**. The contraction in exports is not enough to compensate for the expansion of the other components of aggregate demand. Hence, GDP and production levels are higher with wage growth. Thus, it follows that the industry composition of the output is less carbon intensive in **WTR + wages** than in **WTR**. This is not surprising since internal demand favours growth in less energy-intensive industries such as private and public services instead carbon intensive manufacturing of tradable goods.

6. Concluding remarks

The pursuit of a techno-economic solutions is currently monopolizing the scientific debate on climate change as evidenced by the allocation of funds which are overwhelmingly directed to natural and technical sciences (Foulds and Christensen, 2016; Overland and Sovacool, 2020). On the contrary, a deeper understanding of societal factors would provide adaptation sciences with more reliable analytical tools for assessing the actual feasibility of environmental policies and to design new and more effective ones (Sovacool et al., 2015; Keskitalo and Preston, 2019). In this vein, we have investigated the macroeconomic and environmental implications of a reduction in working time that maintains constant the output per worker. Increases in labour productivity are converted in proportional reductions of working time that result in a scale effect that slows down GDP growth, promotes significant reductions in unemployment rates and greenhouse gas emissions. This is a case to show that social innovations can be as effective as technical solutions towards a low-carbon transition.

We show, through a simple analytical illustration, how working time reduction affects the dynamics of labour income. For a given GDP growth and any sensitivity of wages to employment and productivity, the growth rate of labour income is always higher with working time reduction. This also means that a reduction in working time should shift functional income distribution in favour of workers. Nevertheless GDP is not exogenous and depends dynamically on aggregate demand and employment which interact with prices and wages. We assess this complex picture through scenario analysis by applying Eurogreen, a dynamic macro-simulation model calibrated for France for the period 2014–2050.

Our analysis highlights the emergence of barriers that limit the joint achievement of socio-economic and environmental goals. In the **WTR** scenario, the increase in exports due to a reduction in prices acts as the barrier to the reduction of emissions. In the **GWTR** scenario, the first barrier is overcome by introducing a shrinking of exports that results from a lowering of the relative competitive advantage of the economy. As a consequence, a fiscal barrier consisting in a curtailment of public revenues emerges and negatively affects the employment outcomes. In the **CWTR**, the introduction of a binding fiscal rule addresses the public

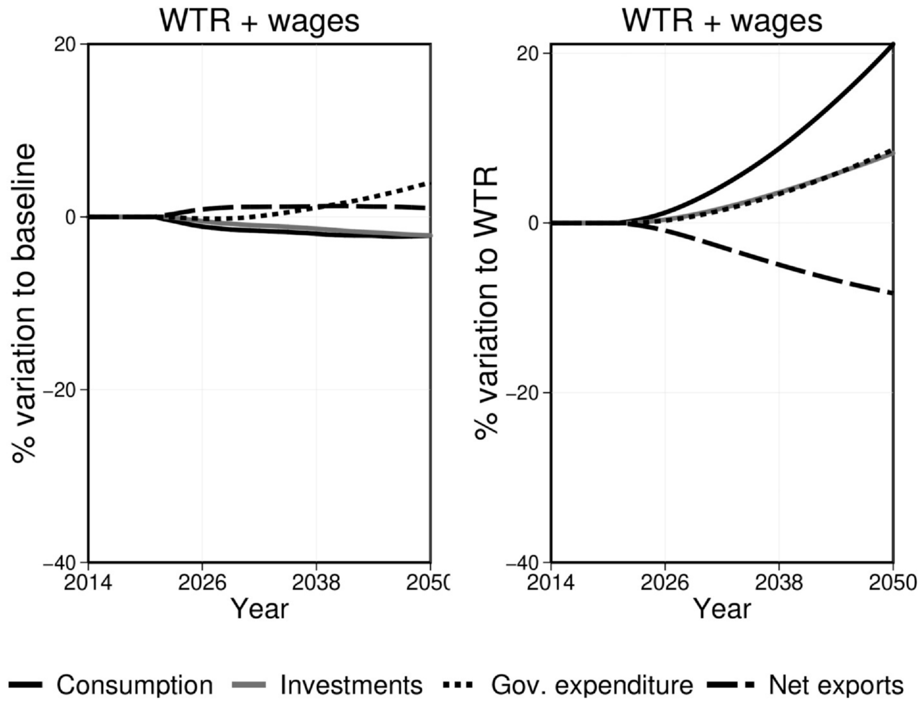


Fig. 7. GDP composition in WTR with wage growth. Comparison between the evolution of private consumption, investments, government expenditures and net exports, in WTR + wages as a percentage of the baseline (left) and WTR (right) values of these components.

deficit barrier and produces the best environmental performance at the cost of the lowest employment outcome. Thus, although productivity-led working time reduction generates a double dividend advantage in all the scenarios, a substantial cut in CO2 emissions would conflict with the objective of sustaining employment. In this sense, we observe that there is a trade-off between the size of employment and environmental benefits even though all working time reduction scenarios achieve an improvement in the two indicators with respect to the baseline. Accordingly, our simulations point out environmental results that are less optimistic – albeit still positive – than other simulation models (Jackson and Victor, 2011).

However, a further social benefit emerge when we add to the picture the circumstance that hourly wages could positively respond to increases in labour productivity. The degree of acceptance of working time reduction by workers is usually tied to the prospect of a constant annual pay, therefore higher hourly wages. Without entering into the merits of the conflict of interests between workers and employees, we limit our analysis to the interactions between income distribution and greenhouse gas emissions under working time reduction. Our results show that it is possible to curb emissions while increasing hourly wages and employment. Nonetheless, in this case it is the expansion of the internal demand that limits GHG emission reductions instead of exports. More interestingly, although the result in term of emission is indistinguishable, the positive response of wage to labour productivity is able to halt the decreasing trend in labour share observed in the **baseline** and the **WTR** scenarios.

Further research should consider whether working time reduction could improve income distribution when individuals in higher-wage occupations reduce their work hours by more than low-wage ones. However, this could be perceived as unfair by low-wage workers. Schor (2005) argues that egalitarian reductions in hours are more likely to be widely accepted since they avoid creating large disparities between groups of workers. Moreover, if employers prefer longer hours, as suggested by Oh et al. (2012), a working time reduction could also accelerate offshoring in tradeable industries.

Since working time reduction reduces imports and might increase exports, it has distributional effects across countries. A GDP contraction in wealthier countries entails a decrease in foreign demand for the poor and could harm employment and inequality in those countries. Such an effect is similar to the sufficiency rebound identified by Alcott (2008) in which a reduction of prices in northern countries that adopt working time reduction results in a increase of exports to the global south.

This study does not explore the interactions between productivity-led working time reduction and *standard* environmental policies, such as carbon tax, subsidies to energy efficiency and renewable energy. Although this can be seen as a shortcoming, it allows us to isolate the effect of a social innovation on emissions. When working time reduction is introduced as a policy (e.g., a contractual change from 35 to 30 hourly week) together with environmental policies, the simulation results show significant complementarities (Cieplinski et al., 2020). However, when working time reduction is tied to labour-productivity growth, the results might change. Indeed, at first, environmental policies should induce a faster implementation of energy-saving technology which could lead to a slowdown in labour-productivity growth and, thus, to a slower decline in working time. This delay would reduce the amplitude of the scale effect and make the achievement of emission targets more dependent on techno-economic solutions. These issues are worth investigating but we leave them for future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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