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THE DISTRIBUTIONAL EFFECTS OF CARBON TAXATION IN ITALY

by Francesco Caprioli* and Giacomo Caracciolo*

Abstract

This paper studies the distributional consequences of introducing a carbon tax – modelled as an energy consumption tax paid by heterogeneous households and firms – in a sectoral general equilibrium OLG model calibrated to the Italian economy. Differences in energy intensity and in the elasticity of substitution between production factors lead to a heterogeneous vulnerability to higher energy prices across sectors. Similarly, high- and low-income households are exposed to energy price changes differently, as the latter devote a larger share of their income to purchasing energy products. We find that, depending on how the government recycles the carbon tax revenue, it is possible to achieve a reduction in energy consumption without harming any household, but only in the long run. Among the redistribution schemes considered, uniform transfers lead to the highest average welfare gains, both in the long term and during the transition. A reduction in the distortionary personal income tax (with a uniform downward shift of the entire average rate schedule) would also make most households better off, although its distributional consequences would be the opposite of those derived from uniform transfers. The former actually benefits poorer households more than richer ones, while for the latter, welfare gains increase further up the income distribution.

JEL Classification: E62, H23.

Keywords: carbon tax, climate change, overlapping generations, revenue recycling.

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1 Introduction

The dire and potentially irreversible consequences of climate change and global warming pose such a major threat for global well-being conditions that the design and implementation of mitigation policies represent two of the main challenges for policy-makers in the 21st century (Nordhaus, 2019). Due to climate change, the frequency and intensity of extreme weather events (such as heat waves, droughts, heavy downpours, floods and hurricanes) is rising: the European Environment Agency estimates that, between 1980 and 2022, weather- and climate-related extremes caused economic losses of assets estimated at EUR 650 billion in the EU Member States, of which above 50 billion euros in 2022 only.[1]. The necessity to reduce global greenhouse gases (GHG) emissions induced various countries to adopt carbon pricing policies. According to the World Bank, in 2023 73 carbon pricing initiatives have been established at different government levels worldwide; these initiatives would cover about 23% of global GHG emissions[2]. Finland and Poland introduced a carbon tax in 1990, making them the first countries to introduce it, followed by Sweden and Norway in 1991, Denmark in 1992 and many other countries over the years[3], while the European Union Emission Trading System (EU ETS) was launched in 2005. In their endeavor to fight climate change, in June 2021 the European Parliament and the Council of the European Union adopted the European Climate Law, that incorporates the ambitious objectives of the European Green Deal: cutting emissions by at least 55% by 2030 compared to 1990 levels and reaching climate neutrality by 2050. Moreover, on the 1^{st} of October 2023, the EU Carbon Border Adjustment Mechanism, designed to prevent the risk of carbon-leakage, entered into application in its transitional phase [4].

Although the consensus on using carbon taxation to mitigate the adverse effects of climate change is widespread, there is a vivid debate on its distributional consequences. A large part of the literature concludes that carbon taxes exacerbate inequality: taxing carbon emissions is found to be regressive (Sterner, 2012; Andersson and Atkinson, 2020; Faiella and Lavecchia, 2021; Känzig, 2021) mostly because energy-intensive goods are typically necessities. Therefore, an increase in their prices may endanger the purchasing power of poorer households disproportionately, as shown in Figure 1.
Other contributions instead, reach the opposite conclusion. Feindt et al. (2021), as an example, point to a mostly neutral or even slightly progressive impact of a European carbon tax at the national level, including Italy, but an overall regressive impact at the aggregate level, due to the strongly negative effect in some poor countries, mostly located in Eastern Europe. Finally, the literature has emphasized that whether a carbon tax produces regressive or progressive effects, as well as its political feasibility, ultimately depends on the way its revenue is rebated to households (Fried et al., 2018, Paoli and Van der Ploeg, 2021).

In this paper, we study the distributional and sectoral consequences of introducing a tax on energy consumption in Italy, and the design of alternative policies aimed at using the associated revenue. Italy represents an interesting case study as, differently from the largest European economies

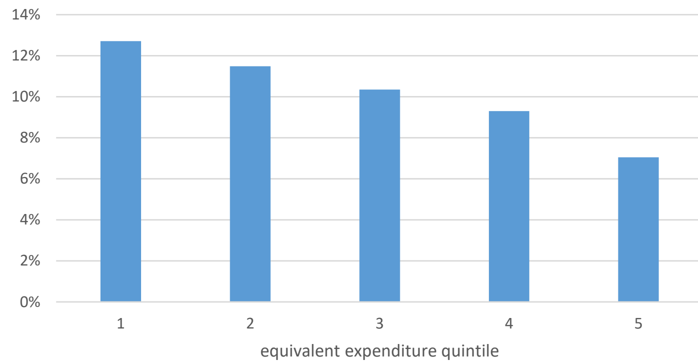
[1] https://www.eea.europa.eu/ims/economic-losses-from-climate-related

[2] https://carbonpricingdashboard.worldbank.org/

[3] In particular: Slovenia in 1996, Estonia in 2000, Latvia in 2004, Iceland and Ireland in 2010, Ukraine in 2011, Japan in 2012, UK in 2013, France, Spain and Mexico in 2014, Portugal in 2015, Colombia and Chile in 2017, Argentina in 2018, Canada and South Africa in 2019, Uruguay in 2022.

[4] For more details: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en .

Figure 1: Expenditure share for electricity, gas and other fuels by equivalent expenditure quintile in Italy (2021, Eurostat)



such as Germany, France and Spain, a national carbon tax outside the scope of the EU ETS is absent. Our analysis sheds light on the welfare impact of introducing a carbon tax and recycling its revenue, given the initial income distribution, the main features of the tax and benefit system and the ability of households and firms to substitute their energy consumption.

To meet this goal, we develop a general equilibrium model with both intra- and inter-generational household heterogeneity and a production network and calibrate it to match the consumption distribution of Italian households and the sectoral composition of the Italian economy. Then, we simulate the effects of introducing an energy tax and we analyze its aggregate and distributional consequences both in the long-run and along the transition. We study the distributional impact of carbon taxation depending on four policy alternatives considered by the government to recycle carbon revenue. In the first, the carbon tax finances an increase in public consumption; in the second scenario, carbon tax revenues are rebated to households with a universal uniform transfer; in the third and in the fourth they are employed to reduce the distortionary taxes respectively on labor and capital income, along the lines of what the literature identifies as the *double dividend hypothesis* (Bovenberg and Goulder, 1996).

In our model, the effect of an energy price increase is twofold. First, given the income distribution, it lowers the purchasing power of poorer households, who devote a larger fraction of total expenditure for the consumption of energy goods. Second, depending on the energy intensity and the elasticity of substitution between energy and the other production factors in the different sectors, an energy price increase affects the optimal demand for factors by firms.

The main results can be summarized as follows. A carbon tax of 75 dollars per CO_2 ton, increasing the price of energy by 10%[5], has a relatively small impact on both aggregate production and prices. Hence, under this assumption our analysis lends support to the adoption of such instrument to fight climate change as inaction would potentially generate higher costs in terms of GDP losses. The same conclusion applies considering the non-environmental welfare losses; our consumption equivalent measure points to a relatively small impact on the aggregate. Nonetheless the distributional properties of this kind of Pigouvian taxation crucially depend on the policy design adopted by the government

[5]In the appendix we perform a robustness exercise in which the same carbon tax increases the energy price only by 5% due to a lower pass-through. The qualitative results are unaffected.

to recycle revenues.

When carbon revenues are used by the fiscal authority to increase government spending, our analysis confirms the regressivity result found by a large part of the literature. The intuition is that for poorest households it is relatively more difficult to substitute the consumption of energy with other goods, being energy a necessity. When, instead, the fiscal authority rebates them via a universal uniform transfer, in the long-run all households are better-off and less productive workers gain more than the skilled ones. Analogously, a cut of distortionary labor income taxes (with an uniform downward shift of the entire average rate schedule) makes all households better-off. Finally, a reduction in the flat capital income tax produces, in the long-run, a small welfare loss, which is flat along the lifetime labor income distribution.

While comprehensive in many respects, the analysis does not address some relevant issued discussed in the literature. First, in the paper we assume only one type of energy, ruling out the possibility that firms may choose technologies with different environmental impacts (for analyses of this type, see Acemoglu et al., 2012; for the role of government in providing incentives to develop greener technologies, see Li et al., 2022). Although we do not explicitly model this possibility, in a robustness exercise we calibrate the pass-through from carbon tax to energy price at values lower than unity, reflecting, in a reduced form way, a situation where firms adopt less carbon-intensive technologies. Secondly, we assume that the carbon tax value is in line with the IMF reccommandation[6], neglecting to characterize optimal taxation, as implemented in Golosov et al. (2014), or the optimal revenue-recycling as in Barrage (2019) and in Fried et al. (2020).

The paper is structured as follows. The remainder of Section 1 summarizes the most relevant literature and clarifies our contribution. Section 2 lays out the model, calibrated according to the strategy outlined in Section 3. Section 4 describes the policy exercises and the the main results of the paper, distinguishing the long-run effects from those arising along the transition. Section 5 concludes.

Related literature

This paper connects with a large and growing literature studying the redistributive properties of carbon taxation (Wang et al., 2016). As documented in Ohlendorf et al. (2021), the existing empirical studies are inconclusive in determining whether environmental policies amplify or mitigate economic inequality. Quantitative results vary with the methodology adopted, the country under examination (Dorband et al., 2019, Feindt et al., 2021), the specific type of goods and services being taxed (Farrell, 2017), the way tax revenues are redistributed (Bovenberg and Goulder, 1996, Metcalf, 1999, Gonzalez, 2012, Chiroleu-Assouline and Fodha, 2014). A large part of the related literature estimates static demand-side effects using microsimulation techniques (Callan et al., 2009, West and Williams, 2018, Berry, 2019, Douenne, 2020, Paoli and Van der Ploeg, 2021) or combining them with input-output analyses (Labandeira and Labeaga, 1999, Renner, 2018). However, indirect and general equilibrium effects (Fullerton and Heutel, 2007) appear to be quantitatively relevant (Känzig, 2021). In general, the empirical evidence suggests that carbon taxes tend to be more regressive in developed countries than in developing ones, where energy-intensive goods and services such as transport and heating turn

[6] As reported by the IMF Managing Director Kristalina Georgieva in her COP26 speech available at https://mediacenter.imf.org/news/imf-georgieva-climate-cop26-carbon-tax/s/6d85380c-df16-4a4c-8d7d-8fb330b38582

out to be luxuries (Sterner, 2012). However, when the associated tax revenues are used to reduce the burden of other progressive taxes – such as payroll taxes and personal income taxes – and/or to increase lump-sum transfers, results tend to change in favor of a slight progressivity. Moreover, Feng et al. (2010) find that by using revenue to increase social benefits and tax credits, a carbon tax can lead to a win-win situation. In the macro public finance literature, the closest paperw to our project are Fried et al. (2018) and Fried et al. (2020). They build an OLG general equilibrium model calibrated to the US economy to study the welfare consequences of carbon taxation for the different cohorts involved in the transition and find that while the generations born in the future long-run steady state prefer a cut in distortionary taxes, the cohorts already alive at the moment of the introduction of a carbon tax benefit more from a uniform transfer. Differently from our paper, there are only two sectors (a foreign energy sector and a domestic non-energy sector) and a very stylized production network. Instead, we allow for a very rich structure of heterogeneity across sectors, to analyze the role played by the production network and we calibrate the model to the Italian economy.

The main contribution of this paper is to analyze, in a general equilibrium framework, the distributional consequences of green policies at the sectoral level. Other papers (among many others, Goto, 1995, Gonne, 2016) have answered this question in a partial equilibrium analysis. Later on, we highlight the differences between the two approaches in terms of quantitative results. In Section (3) we show that different sectors have different degrees of resilience to higher energy prices, either because their energy intensity is lower or they can substitute more easily energy with other production factors.

2 The model

Three types of agents populate the economy: households, firms and the government. The demand side of the model is characterized by an OLG structure where J cohorts coexist in each period, which is equal to one year. Besides the inter-generational heterogeneity, households differ along the income dimension within each generation, as determined by labor productivity, asset holdings and public pension entitlements. In the model, the wealth distribution is generated by differences in initial conditions (ex-ante heterogeneity) as well as idiosyncratic productivity shocks (ex-post heterogeneity). While the household problem is dynamic, firms' decisions are the result of static optimization.

Firms in each sector are perfectly competitive and use a nested constant elasticity of substitution (CES) production function with constant returns to scale. One of the production factors is energy, which is entirely produced abroad and exchanged for consumption goods with zero trade balance in every period. This assumption seems relatively harmless, as the Italian GDP share of domestically produced Electricity, Gas, Steam and Air Conditioning Supply (NACE sector D) is around 2.6% according to 2017 Istat input/output tables. Moreover, we treat the domestic economy as small and open with respect to the energy market. Hence, the world price is insensible to variation in the energy demand by domestic firms and households. Firms' output can be either consumed by households and by the government or used as intermediate input by firms in the other sectors. In response to changes in the carbon tax, firms are not allowed to switch from "dirty" to "green" inputs, as analyzed by Acemoglu et al. (2012), as our setup does not distinguish fossil from renewable energy sources. Moreover, the pass-through of the carbon tax on the energy price is the same across sectors. A heterogenous pass-through would matter quantitatively in the case in which the energy composition (electricity, natural gas, fuels etc.) varied substantially across our sectors. Instead, we assume that such composition is homogeneous because our sectors are relatively large. Therefore different sectors have a different carbon footprint, even though the mechanism is not heterogeneous energy composition, but relies on heterogeneous energy intensity. The rich production structure allows to take into account all the network interactions among different sectors; calibrating the model with input-output Italian data, it turns out that the network component is quite relevant and crucial to simulate the propagation of price changes to the other sectors.

The government is assumed to run a balanced budget in each period; it sets a progressive labor income tax and a proportional capital income tax to finance an exogenous stream of consumption. Furthermore, it collects social security contributions from employers and employees to finance a defined contribution PAYG system. The replacement rate is adjusted in each period to ensure the balance between total contributions and total benefits. For the sake of tractability, we approximate the overall progressivity of the Italian personal income tax using the Gouveia and Strauss (1994) functional form, without incorporating all of its details. The carbon tax is modelled as an import tariff on energy, as in Fried et al. (2018)[7].

The proposed setup does not belong to the class of integrated assessment models (Nordhaus, 2013, Golosov et al., 2014) as it does not incorporate a climate module where economic decisions affect the amount of CO_2 emissions, which, in turn, alter agents' well-being conditions or firms productivity. In other words, the welfare effects presented in our analysis do not account for the impact of environmental conditions on households' utility. Although this simplification means that the costs of inaction (i.e. not introducing climate change mitigation instruments as the carbon tax) and how they are distributed in the population cannot be computed through the lenses of the model, they are beyond the scope of this analysis. In our approach we choose to treat the green transition as a necessary development of the Italian economy, as the enforcement of the already existing EU ETS suggests, and take the optimal level of carbon taxation as exogenous for an economy being small relative to global emissions. In the quantitative simulations we compare the income distribution arising in an initial steady state, without carbon taxation, and a long-run one where carbon taxes are in place and alternative revenues recycling schemes can by implemented by the fiscal authority. Hence, we do not interpret the starting stationary equilibrium as the potential long-run outcome of climate policy inaction, but rather one representing the conditions of Italian economy at the beginning of the green transition, as we aim to capture what, in our view, appears to be the most realistic and policy-relevant comparison.

The model is solved with standard numerical methods. In the following, we save on notation by leaving the time subscripts implicit.

[7]An alternative way to model the introduction of a carbon tax would be to explicitly consider the EU ETS, the cornerstone of EU climate change policy. For the time being we ignore it in our analysis, as the ETS covers only around 40% of overall EU greenhouse gas emissions, while we aim to study the effects of an economy-wide green transition. Anyway, the existing literature seem to support the idea that a carbon tax and a cap and trade system are equivalent (Golosov et al., 2014).

2.1 Households

Households enter the economy at model age $j = 1$ with zero assets, work until age J^r, live until the maximum age J and maximize lifetime utility with respect to consumption, labor supply and savings. Lifespan is uncertain: only a fraction $s(j)$ of the cohort aged j transitions into the next period. The problem of the household can be summarized by the following Bellman equation:

$$V(a, z, ea, j) = \max_{C,l,a'} \quad u(C, l) + s(j)\beta EV\left(a', z', ea', j + 1\right) \tag{1}$$

where β is the discount factor and $s(j)$ is the age-specific survival probability. The individual state variables are: a, the asset position at the beginning of the period; z is the persistent level of individual labor productivity; ea, the average earnings obtained during the lifetime and age j. The choice variables are: consumption C, labor supply l and savings a'. Temporal utility u is increasing in consumption C and decreasing in labor supply l and is assumed to take the following functional form:

$$u\left(C, l\right) = \frac{C^{1-\frac{1}{\rho}}}{1 - \frac{1}{\rho}} - \chi\frac{l^{1+\nu}}{1 + \nu} \tag{2}$$

where ρ is the consumption intertemporal elasticity of substitution, χ is the weight of the disutility from labor in the utility function, ν is a parameter governing the Frisch elasticity. Moreover, C is a consumption aggregator of 6 different consumption goods and is characterized by the Stone-Geary (Geary, 1950) specification:

$$C = \prod_{n=1}^{6}\left(c_n - \bar{c}_n\right)^{\omega_n}$$

Parameters $\{\bar{c}_n\}_{n=1}^{6}$ give the subsistence level for each one of the goods consumed (energy, agriculture, manufacturing, construction, services and public services); the parameters $\{\omega_n\}_{n=1}^{6}$ govern their expenditure share and are such that $\sum_{n=1}^{6}\omega_n = 1$. Preferences are therefore non-homothetic, which allows us to explicitly model heterogeneous consumption shares along the income distribution by identifying necessity and luxury goods. Households maximize the value function in (1) subject to a set of constraints:

$$\left(1 + \tau^c\right)p_1 c_1 + \sum_{n>1}^{6} p_n c_n + a' = R(j)a + \left(1 - \mathbb{1}_{j>J^r}\right)y + \mathbb{1}_{j>J^r}pen + T \tag{3}$$

$$y = (1 - \tau^w)wh(j)l\left[1 - \tau^y((1 - \tau^w)wh(j)l)\right] \tag{4}$$

$$pen = \xi ea\left[1 - \tau^y(\xi ea)\right] \tag{5}$$

$$ea' = \begin{cases} ea & \text{if } j > J^r \\ \frac{jea + wh(j)l}{j+1} & \text{if } j \leq J^r \end{cases} \tag{6}$$

$$R(j) = \frac{1 + r(1 - \tau^k)}{s(j)} \tag{7}$$

$$log\left(h\left(j\right)\right) = z + d(j) \tag{8}$$

$$z = \rho_z z_{-1} + e \quad e \sim \mathcal{N}(0, \sigma_e^2) \tag{9}$$

$$z_1 \sim \mathcal{N}(0, {\sigma_z}_1^2) \tag{10}$$

$$a' \geq 0 \tag{11}$$

Equation (3) defines the temporal budget constraint, where good 1 is energy, τ^c is the carbon tax incidence on energy consumption, a' is savings, $R(j)a$ is capital income, y is net labor income, which is only earned when young and working (i.e. $j \leq J^r$), pen is net pension income, which is claimed only once old and retired (i.e. $j > J^r$) and T is a government transfer. Equation (4) states that net labor income y corresponds to gross labor income $wh(j)l$ - where w is the wage rate in efficiency units, $h(j)$ is overall individual labor productivity and l is the amount of hours worked - net of employee social security contributions and income taxes. In particular, τ^w is the flat employee contribution rate, while income is subject to progressive taxation, with the average tax rate $\tau^y(x)$ following the Gouveia and Strauss (1994) specification:

$$\tau^y(x) = t_1 \left[1 - \left(t_2 x^{t_3} + 1\right)^{-\frac{1}{t_3}}\right] - t_4 \tag{12}$$

with t_4 initially set to 0. Equation (5) defines net pension income as gross pension income ξea net of income taxes. The gross pension benefit is a proportion ξ of working life average earnings ea. The evolution of the latter over the life-cycle is expressed by equation (6). We assume the presence of perfect annuities markets, that allow households to perfectly insure against longevity risk, as in Ríos-Rull (1996). This implies that the gross interest $R(j)$, defined in equation (7), is the return on capital investment r net of a proportional capital income taxation with a tax rate τ^k plus the principal, discounted for the survival probability $s(j)$. Individual productivity $h(j)$ at age j follows the process in equation (8): $d(j)$ is a deterministic age-dependent component common to all workers, z is an idiosyncratic persistent component evolving over time according to the Markov process in equation (9). $h(j)$ is assumed to be 0 for $j > J^r$, which implies $l(j) = 0$ for $j > J^r$ in the solution of the household problem. Both e and z_1 are normally distributed with 0 mean and constant variance (equations 9 and 10). Finally, we assume that households face a no-borrowing constraint (equation 11).

2.2 Firms

The production side of the domestic economy is populated by 5 sectors[8]. There is a representative firm in each sector, solving a static profit maximization problem with a constant returns to scale production function and a rich production network. All firms employ a combination of labor, capital, energy and intermediate inputs to produce their output. The production function of sector n is:

$$Y(n) = A \left\{ \left[\alpha_n \left(K(n)^{\epsilon_n} L(n)^{(1-\epsilon_n)} \right)^{\frac{\iota_n - 1}{\iota_n}} + (1 - \alpha_n) E(n)^{\frac{\iota_n - 1}{\iota_n}} \right]^{\frac{\iota_n}{\iota_n - 1}} \right\}^{\psi_n} \left\{ \prod_{s \neq n, 1}^{6} \left(Y^d(s, n) \right)^{\theta_{s,n}} \right\}^{(1-\psi_n)} \tag{13}$$

[8] The 5 production sectors correspond to the 6 consumption goods minus energy, which is produced abroad and imported.

where α_n, ϵ_n, ι_n, ψ_n, $\{\theta_{s,n}\}_{s\neq n,1}^{6}$ are sector-specific parameters, governing respectively the share of the labor/capital composite relative to energy, the share of capital in the labor/capital composite, the elasticity of substitution between energy and the labor/capital composite (which are gross complements when $\iota_n < 1$ and gross substitutes otherwise), the factor share of intermediate inputs relative to the labor/capital/energy aggregator and the factor share of the output produced by sector s in the production of sector j (subject to the condition that $\sum_{s\neq n,1}^{6} \theta_{s,n} = 1$ for each n). Instead, A is aggregate productivity, which is common across sectors. Both goods and factors markets are perfectly competitive and prices are fully flexible, so that goods (factors) are priced their marginal cost (product) and firms make zero profits. Therefore, the problem solved by the representative firm producing in sector j is:

$$\max_{K(n),L(n),E(n),Y^d(s,n)} p_n Y(n) - (r+\delta)K(n) - w(1+\tau^f)L(n) - p_1(1+\tau^c)E(n) - \sum_{s\neq n,1}^{6} p_s Y^d(s,n) \quad (14)$$

where r, w are the economy-wide return of capital and the sector-specific wage per efficiency unit, δ is the economy depreciation rate of capital and τ^f is the employer social security contribution rate.

2.3 Government

The government runs a balanced budget in each period. It levies taxes on income according to a dual system: the capital income tax is flat, with a tax rate τ^k, while personal income (labor income and pensions) is subject to a progressive taxation regime with an average tax rate τ^y (equation 12). Energy consumption is taxed with the tax rate τ^c, set to 0 in the initial stationary equilibrium. Furthermore, the government consumes an exogenous amount G of total production, which is allocated across the different goods according to the consumption shares $\{\omega_j^g\}_{j=1}^{n}$ (with $\sum_j^n \omega_j^g = 1$) and redistributes resources to households with transfers T (set to 0 in the pre-tax stationary equilibrium). In the following quantitative exercises, we simulate the effects of alternative ways of recycling carbon tax revenues by the government. Under a first scenario, denominated *government spending*, the carbon tax finances an increase in G. In the second scenario, defined *uniform transfer*, carbon tax revenues are rebated to households with a universal uniform transfer T and public expenditure G is only funded by capital, labor and pension income taxation. In the third policy simulation carbon tax revenues are employed to promote a reduction in progressive personal income tax rates, resulting from an adjustment in the policy parameter t_4. Any movement in t_4, with t_1, t_2 and t_3 being constant, implies a parallel shift of the personal income average tax rate for each income level. We refer to this case as *labor income taxes* scenario. Finally, in the last scenario, denominated *capital income taxes*, we assume that carbon tax revenues are used to reduce the tax rate τ^k on capital income. Regardless of the specific policy option, in every period the government budget constraint holds:

$$G+T\sum_{j=1}^{J} N(j) = p_1\tau^c \left(\sum_{n=2}^{6} E(n) + \sum_i c_1(i)\gamma(i)\right) + \sum_i \left\{\tau^y \left[(1-\tau^w)\, wh(i)l(i)\right](1-\tau^w)\, wh(i)l(i) + \tau^y\left[\xi ea(i)\right]\xi ea(i) + \tau^k ra(i)\right\}\gamma(i) \quad (15)$$

where $\gamma(i)$ represents the mass of household i and $N(j)$ is the overall mass of agents aged j, so that $N(j+1) = s(j)N(j)$[9]. In the four different policy exercises, the government budget constraint is

[9]We assume that $N(j=1) = 1$.

Table 1: Policy parameter adjusting to satisfy the government budget constraint

Policy experiment	Denomination	Parameter adjusting
1	Government spending	G
2	Uniform transfer	T
3	Labor income taxes	t_4
4	Capital income taxes	τ^k

satisfied via an adjustment of a different parameter, as reported in Table (1).

The government runs also a separate PAYG social security budget, which is also balanced in each period through an endogenous adjustment of the replacement rate ξ, as in a standard defined contribution scheme:

$$\tau^w w \sum_i h(i)l(i)\gamma(i) + \tau^f w \sum_{n=2}^{6} L(n) = \xi \sum_i \left\{ \mathbb{1}_{j>J^r}(i,j)ea(i,j) \right\} \gamma(i) \tag{16}$$

The LHS of equation (16) amounts to total PAYG contributions, where τ^w and τ^f are respectively the employee and employer contribution rates; the RHS is the total amount of public pension benefits paid to retired workers.

2.4 Equilibrium

In this economy, an equilibrium consists of series of idiosyncratic shocks $\{\epsilon(i,j), k(i)\}$, a vector of policy variables $\{\tau^k, \tau^c, G, t_4, T, \xi\}_{t=0}^{\infty}$, a vector of endogenous prices $\{w, r, p_n\}_{t=0}^{\infty}$ and the associated allocation of resources, such that, in each period[10]:

- all households maximize their lifetime utility with respect to the consumption of each good, savings and labor supply;
- all representative firms in each sector maximize their profits with respect to capital, labor, energy and intermediates;
- the government, depending on the scenario, adjusts the relevant policy parameter to satisfy its temporal budget constraint;
- the government adjusts the policy parameter ξ to satisfy the PAYG budget constraint;
- all goods (which are also production factors) markets clear, including the international energy market;
- all the labor markets and the capital market clear.

3 Calibration

The calibration of all the preference, technology and fiscal policy parameters of the outlined model to the Italian economy follows a composite strategy. A first group of parameters is calibrated to values

[10] A detailed account of the computational algorithm employed to solve the model is described in Appendix B.

typically assigned in the related literature. This is the case for the parameters ρ, ρ_z and ν, which are respectively set to 0.5, 0.98 and 2, and for the sector-specific energy elasticity of substitution ι_n. The values for the latter are directly taken from Baccianti (2013), who estimates ι_n at the European level, under the assumption of a sectoral production function analogous to the one we adopt.

The second group of parameters are externally calibrated to the data available for the Italian economy. The Italian Statistical Office (Istat) input-output tables by production sector provide the information needed for the parameters $\{\alpha_n, \epsilon_n, \psi_n, \theta_{s,n}\}_{n=2}^{6}$, that typically govern the factor share of each input in each sector. In order to reduce the computational cost of solving the model and with a reasonable sacrifice in terms of information content, we group some sectors so that the original data, available for 20 sectors, are converted into 6-sector data. The scheme we employ is presented in table (3)[11]. In order to calibrate $\{\omega_n^g\}_{n=1}^{6}$, i.e. the government expenditure shares among the considered sectors, we use the *Cofog* data published by Eurostat. The vector of age-dependent survival probability $\{s(j)\}_{j=1}^{J}$ is obtained from Istat data, while the age-specific productivity component $\{d(j)\}_{j=1}^{Jr}$ is estimated from administrative data provided by the Italian social security institution, INPS, following the empirical strategy outlined in Kaplan (2012) and Tasso (2020). Moreover, we assume that agents enter the labor market at age 26 (model age $j = 1$), retire at age 62 ($Jr = 37$) and live until the maximum age of 95 years ($J = 70$).

The last group of parameters is calibrated internally, minimizing a quadratic loss function of the difference between the moments generated by the model and their empirical counterparts. The parameters of the Gouveia-Strauss (governing the progressive income tax schedule, with t_4 set to 0) and Stone-Geary (modelling the utility function) specifications belong to this group, as well as β, χ, δ, σ_{z1}^2, σ_e^2 and p_1. The main data targets are the aggregate capital-output (3.3) and investment-output (0.2) ratios, the average fraction of hours spent working (0.33), the energy consumption share by the household sector (0.32), the variance of (log) earnings at 26 and 62 (0.28 and 0.58 respectively). A further target of our calibration procedure is the consumption share of each of the 6 products along the labor income distribution. The *Household Budget Survey* conducted by Istat is the main data source for the consumption patterns of the quintiles of the Italian consumption distribution. Energy consumption[12] is defined as the sum of COICOP categories 045 "Electricity, gas and other fuels", and 0722 "Fuels and lubricants for private transport". We transform the expenditure data in the NACE format using the conversion matrix for Italy, estimated by Cai and Vandyck (2020). Finally, we resort to the statistical matching between the income data contained in the *Survey of Household Income and Wealth* (SHIW) conducted by the Bank of Italy and the consumption data available in Istat *Household Budget Survey* performed by the Bank of Italy microsimulation model *BIMic* (Curci et al., 2017), to calibrate the income quintile-specific personal income average tax rate.

Figure (2) displays the model fit in replicating the consumption expenditure patterns by sector and expenditure quintile as observed in the data.

[11] Our definition of energy includes the output of sector D "Electricity, Gas, Steam and Air Conditioning Supply" and the output of sector C19 "Coke and Refined Petroleum Products".

[12] Energy consumption by households as a share of total energy consumption in Italy amounted to 32% in the period 2017-20, according to MASE (2023).

Figure 2: Model fit - consumption shares for each good by total expenditure quintile (%)

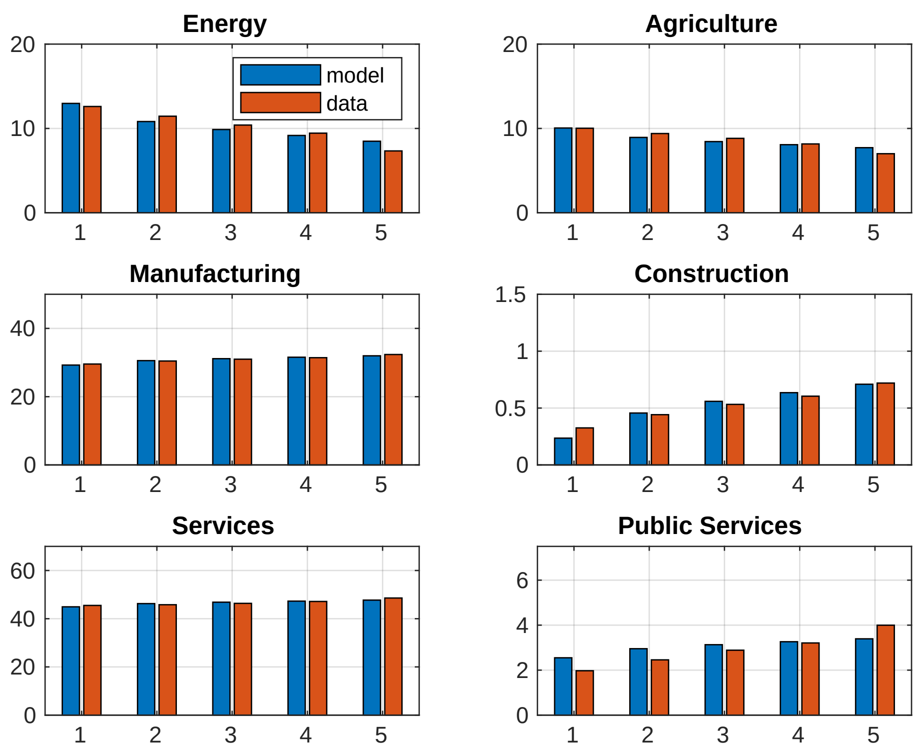


Table 2: Calibration

Parameters	Symbol	Value	
Parameters taken from the literature			**Source**
Elasticity of intertemporal substitution	ρ	0.5	Standard in the literature
AR(1) componenent of the earnings process	ρ_z	0.98	Standard in the literature
Inverse of Frisch elasticity of substitution	ν	2	Standard in the literature
Energy elasticity of substitution	$\{\iota_n\}_{n=2}^{6}$		Baccianti (2013)
Parameters estimated directly from the data			**Source**
Capital share in the K-L composite	$\{\epsilon_n\}_{n=2}^{6}$		Istat I/O tables
K-L share in the K-L-E composite	$\{\alpha_n\}_{n=2}^{6}$		Istat I/O tables
Complement of the intermediate input share	$\{\psi_n\}_{n=2}^{6}$		Istat I/O tables
Sector i product share in the intermediate input of sector n	$\{\theta_{i,n}\}_{i\neq n,1}^{6}$		Istat I/O tables
Sector n expenditure share in government consumption	$\{\omega_n^g\}_{n=2}^{6}$		Eurostat
Age-dependent survival probabilities	$\{s(j)\}_{j=1}^{J}$		Istat
Age-dependent productivity profile	$\{d(j)\}_{j=1}^{Jr}$		INPS
Employer and employee social security contribution rates	$\{\tau^f, \tau^w\}$	$\{0.2381, 0.0919\}$	INPS
Capital income tax rate	τ^k	0.309	
Parameters calibrated matching some data moments			
Rate of time preference	β	0.98	
Weight of labor disutility	χ	120	
Private consumption shares	$\{\omega_n\}_{n=1}^{6}$		
Subsistence consumption levels	$\{\bar{c}_n\}_{n=1}^{6}$		
Gouveia-Strauss labor income tax parameters	$\{t_1, t_2, t_3\}$	$\{0.40, 6.89, 1.58\}$	
Depreciation rate	δ	0.06	
Energy price	p_1	0.24	
Variance of initial earnings	$\sigma_{z_1}^2$	0.36	
Variance of transitory earnings process component	σ_e^2	0.032	
Data moments			**Source**
Aggregate capital-output ratio		3.3	
Aggregate investment-output ratio		20%	
Average time spent working		$\frac{1}{3}$	
Energy consumption share of households		32%	MASE (2023)
Variance of log earnings at age 26		0.28	INPS
Variance of log earnings at age 62		0.58	INPS
Consumption expenditure shares by expenditure quintile			Istat HBS
Income average tax rate by income quintile			Istat & Curci et al. (2017)

Table 3: From NACE Rev. 2 sectors to our model sectors

NACE Rev. 2 sectors		Model sector	Model sector name
A	Agriculture, Forestry and Fishing	2	Agriculture, mining and water
B	Mining and Quarrying		
C	Manufacturing	3	Manufacturing
C19	Manufacturing - Coke and Refined Petroleum Products	1	Energy
D	Electricity, Gas, Steam and Air Conditioning Supply	1	Energy
E	Water Supply; Sewerage, Waste Management and Remediation Activities	2	Agriculture, mining and water
F	Construction	4	Construction
G	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	5	Services
H	Transportation and Storage		
I	Accommodation and Food Service Activities		
J	Information and Communication		
K	Financial and Insurance Activities		
L	Real Estate Activities		
M	Professional, Scientific and Technical Activities		
N	Administrative and Support Service Activities		
O	Public Administration and Defence; Compulsory Social Security	6	Public services
P	Education		
Q	Human Health and Social Work Activities		
R	Arts, Entertainment and Recreation	5	Services
S	Other Service Activities		
T	Activities of Households as Employers; Undifferentiated Goods and Services...		

Table 4: Calibration of the production parameters by sector

Sectors	ϵ	α	ι	ψ
Agriculture, mining and water	0.7	0.97	0.6	0.7
Manufacturing	0.4	0.98	0.2	0.7
Construction	0.5	1	0.1	0.6
Services	0.7	0.99	0.4	0.9
Public services	0.3	0.98	0.4	0.7

Table (4) contains the calibration of the production parameters, as derived from the input-output tables published by Istat and as resulting from the estimation performed in Baccianti (2013). The information provided by the table can be used to assess 1) the relative importance of energy for the production of the other goods and services and 2) how an increase in the energy price would affect the allocation of factors across sectors. In particular, the impact would be larger in those sectors where: (i) the energy share is large (implied by a low value α_n); (ii) a low elasticity of substitution ι_n between energy and the labor/capital composite production factor; (iii) a low intermediate input share, as measured by $(1-\psi_n)$. We can observe that α_n is generally very close to 1 in all sectors, with Agriculture, Mining and Water, Manufacturing and Public services sectors being the most energy-intensive. Secondly, ι_n are all smaller than 1, indicating gross complementarity between energy and the other factors of production, as documented by Hassler et al. (2021).

Construction and Manufacturing appear as the sectors where it is most difficult to substitute the use of energy as an input. Furthermore, the share of intermediate goods is non-negligible in all sectors, suggesting that the network component is important - especially for agriculture, Manufacturing, Construction and Public Services - to simulate the propagation of price changes across goods. Finally, it is worth noting that the calibration of the pre-tax steady state for the Italian economy factors-in the impact of the already existing EU Emissions Trading System on relative prices. Therefore, the impact of introducing an economy-wide carbon tax should be interpreted as additional to the pre-existing carbon pricing, resulting from the implementation of the EU ETS. The results of our calibration procedure are summarized in table (2).

4 The policy exercises

In this section we simulate the effects of introducing a carbon tax in the Italian economy under the four alternative fiscal policy options outlined before. In this setup, we model a carbon tax as an import tariff on the goods and services produced by the foreign energy sector. In our model, the value of 75$ per CO_2 ton – as recently proposed by the IMF[13] – implies a permanent increase in the tax rate on energy consumption τ^c from 0 to 10%[14].

In order to account for an imperfect pass-through of carbon taxes on the energy price, as determined by the partial dependence of the Italian total energy demand on fossil fuels and the potential implementation of adaption strategies by firms (such as resorting to renewable and green energy sources), in the appendix we conduct a sensitivity analysis where the tax rate τ^c increases only to 15%.

The main object of interest of our analysis is ex-post welfare. We measure it in terms of consumption equivalent variation (CEV), a standard measure of the welfare impact of a policy change. In practice, it corresponds to the relative variation in consumption that agents would need in each period of their lifetime to be indifferent between the outcome generated by the policy reform and the one arising absent any policy change. A negative CEV indicates that the agent must be compensated to "accept" the introduction of the carbon tax and the associated revenues-recycling alternative. On the contrary, a positive CEV is an index of welfare gains induced by the redistribution scheme. Let us identify household i as one characterized by a draw of the initial productivity level z_1, the sequence of idiosyncratic shocks $\{e(j)\}_{j=2}^{Jr}$ and living until the maximum age J. Moreover, we define $W^b(i)$ her ex-post (so given the realization of all income shocks and under the hypothesis of surviving until age J) lifetime utility under the redistribution scheme b:

$$W^b(i) \equiv \sum_{j=1}^{J} \beta^{j-1} u \left[C^b(i,j), l^b(i,j)\right] \tag{17}$$

$\{C^a(i,j), l^a(i,j)\}_{j=1}^{J}$ is the sequence of consumption and labor supply choices made by the same household in the pre-tax stationary equilibrium. Then her CEV, associated to the b scenario, solves the following equation:

$$W^b(i) = \sum_{j=1}^{J} \beta^{j-1} u \left[(1 + CEV^b(i))C^a(i,j), l^a(i,j)\right] \tag{18}$$

4.1 The long-run effects

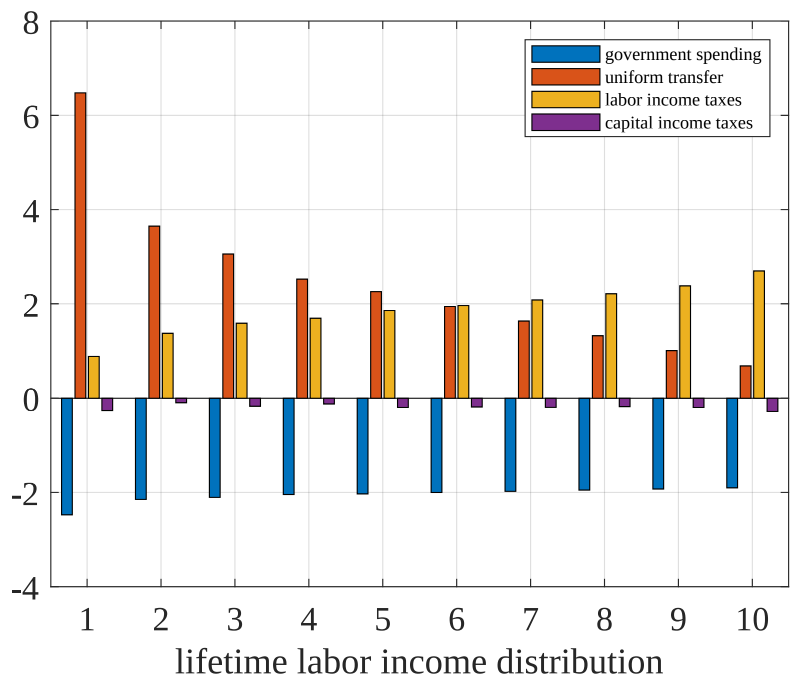
Figure (3) shows the CEV for the lifetime labor income distribution, as proxied by the state variable ae (average earnings) at retirement age Jr, arising in the pre-tax stationary equilibrium. When the

[13] Check the IMF Managing Director Kristalina Georgieva speech at the COP26 available at https://mediacenter.imf.org/news/imf-georgieva-climate-cop26-carbon-tax/s/6d85380c-df16-4a4c-8d7d-8fb330b38582

[14] The value of 10% is derived from an average calculation, reflecting the price, consumption (used as a weight) and emission factor of: petroleum products, natural gas and electricity. A similar estimated increase can be found in Faiella and Lavecchia (2021)

carbon tax finances an increase in government spending, the values are negative and decreasing along the income distribution: in this case the carbon tax is more detrimental for poor households. This is in line with the result commonly found in the literature, related to the higher energy expenditure share for the individuals at the bottom of the income distribution. On the other hand, a uniform transfer (amounting to almost 400 euros per capita) reverts this result; all agents are better-off in the new steady-state. Moreover, the transfer has a progressive impact as poor households benefit relatively more than rich ones. In fact, in nominal terms, the latter contribute to the energy tax revenues more than the former and the loss in purchasing power suffered by the poorest households is more than offset by the transfer. Thirdly, a reduction in labor income tax rate of almost 3.4 percentage points benefits all deciles [15]. Compared to the previous exercise, this redistribution scheme is more favourable for the richest households, as they benefit more from the reduction in the relatively higher distortionary labor income tax. Concerning the last fiscal adjustment, the reduction in the capital income tax rate from 30.9% to 26.0% generates a small welfare loss for everyone. The intuition for a negative CEV is that the welfare gain due to the reduction in τ^k is outweighted by the increase in all prices.

Figure 3: CEV by income decile (%)



The introduction of the environmental policy produces a reallocation of factors across sectors and an overall recomposition of output. Figure (4) shows the percentage change – compared to the pre-carbon tax steady state – of the production of each sector for the four fiscal policy options considered. When the government uses the carbon tax revenues to finance an increase in G, the production in all sectors drops, except for Construction and Public Services, where it increases due to the bias of public

[15] As explained at the beginning of section 4, the fiscal authority can reduce labor income taxes in multiple ways. The results we show are obtained under the assumption that it is the parameter t_4 to adjust, which translates into a constant variation in the average labor tax rates faced by all income classes.

Figure 4: The production response to a carbon tax (percentage change)

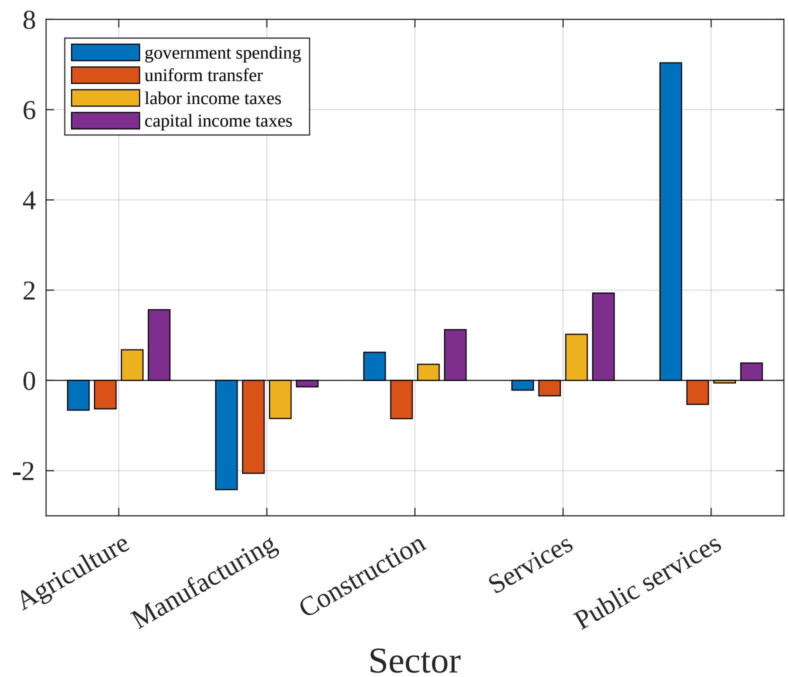
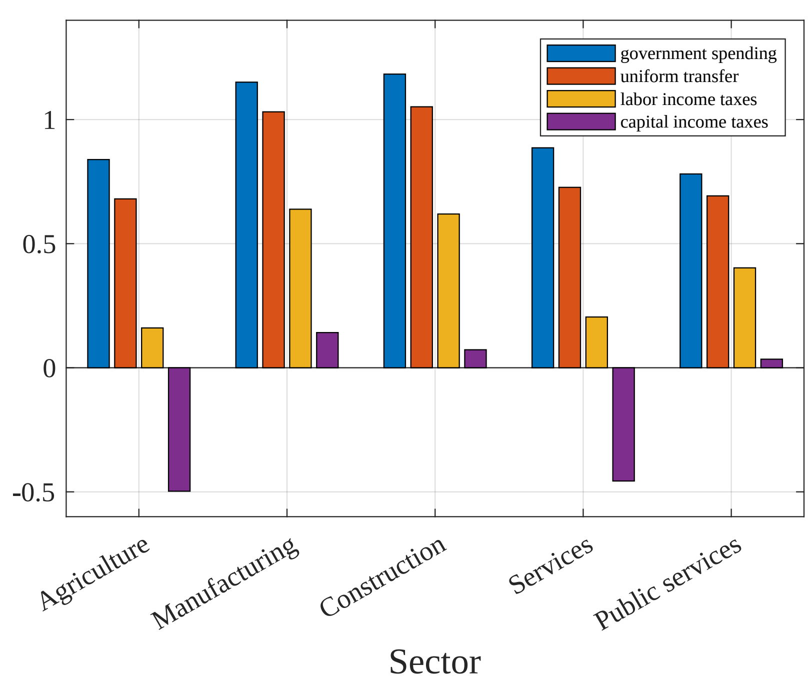


Figure 5: Percentage change in goods prices



spending. When revenues are rebated by a uniform transfer, production decreases in all sectors. Under the third and the fourth policy options, instead, output increases in all sectors, with the exception of Manufacturing. This difference in the output response across sectors reflects the asymmetric impact that the alternative policy schemes have on labor and capital supply. In fact, a uniform transfer favors an increase in disposable income and, therefore, a decrease in labor supply; under the first scenario, instead, the increase in government spending forces workers to increase their labor supply only in the Public Services and Construction sectors, and decrease it in the others; under the last two scenarios, the fall in labor and capital taxation stimulates production in all sectors by fostering the supply of the production factors.

Figure (5) shows the price response to the carbon tax. Overall, prices increase relative to the initial steady state[16] under the first three policy scenarios, because of both firms' higher intermediate costs and the substitution of energy with other goods on the demand side. From a quantitative point of view however, the prices surge is quite limited, as the share of (our definition of) energy as intermediate input is relatively small. On the contrary, in the last scheme prices are substantially stable and adjust downwards in Agriculture and Services as a result of a higher capital supply, coherently with the relative output increase.

The first goal of the environmental policy is to stimulate some energy saving. Therefore, two important questions for the policy-maker could be whether the energy tax is effective in reaching this objective and whether it depends on the choice of the specific rebating scheme. Figure (6) displays the decline in energy consumption determined by the introduction of the environmental policy, which amounts to around 4% on average across scenarios. The decrease is quite different depending on the redistribution policy (namely larger for the first two schemes) and substantially larger for households than for firms, suggesting the choice of the specific redistribution instrument matters for the emissions reduction policy goal. In particular, redistributing the carbon tax revenue by reducing the tax wedges on labor or capital is relatively less effective in stimulating energy saving because of the indirect positive effect on output. These compensating schemes, by fostering labor and capital supply, partly offset the reduction in activity due to the environmental policy.

One of the concerns surrounding the adoption of carbon taxes is the potential side effect of tax base erosion, i.e. the possibility that it may reduce the government revenues from other forms of taxation. Our results suggest that the tax erosion induced by imposing the energy tax should not represent a major threat for the sustainability of public finances, as the effects are quantitatively limited. Figure (7) shows the change in labor and capital tax revenue across policy experiments. As expected, when carbon tax revenue are employed to reduce distortionary taxation, the corresponding revenue falls. This is the case for the third and the fourth redistribution schemes, where the reduction in the tax rates constitutes the intended consequence of the policies enacted. Moreover the fall in the revenue for the labor tax in the third scenario appears quantitatively similar to the one of the capital income tax in the fourth. The unintended consequences of carbon taxation on the capital and labor tax bases involve instead the other policy scenarios. However, with reference to these, overall movements in the tax bases appear very small; in particular, the introduction of the carbon tax increases the labor tax base under the first adjustment, while it erodes both labor and capital tax bases under the second.

[16]The introduction of the carbon tax alters permanently the prices of the different goods. However, inflation is zero both in the initial and in the final steady state.

Figure 6: Percentage change in energy consumption by households and firms

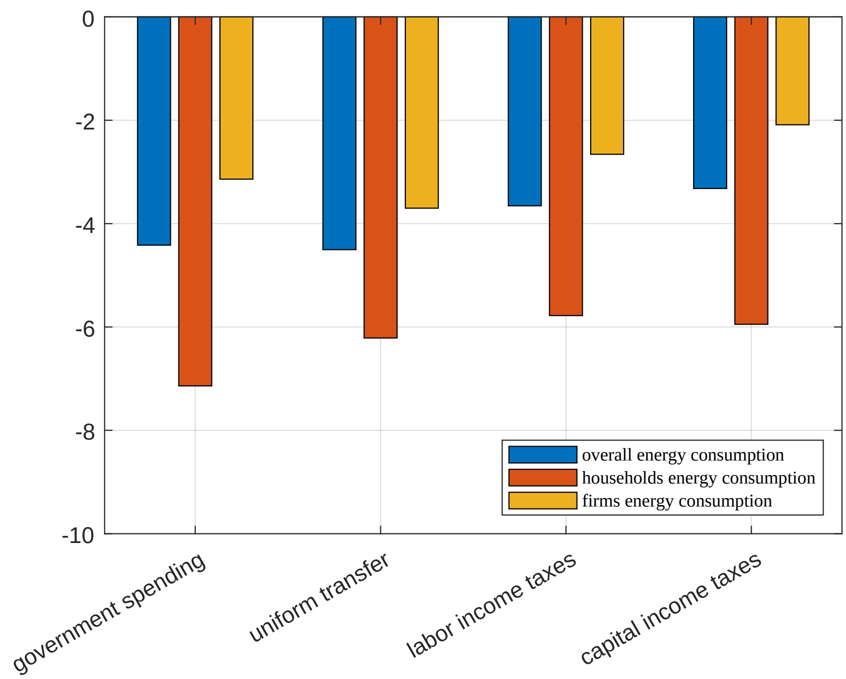
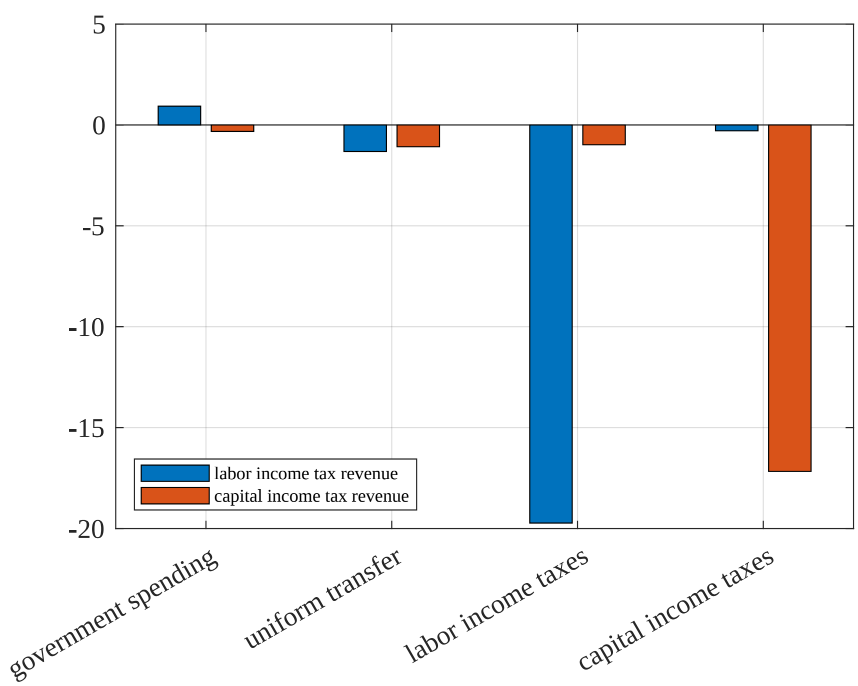


Figure 7: Percentage change in labor and capital tax revenue



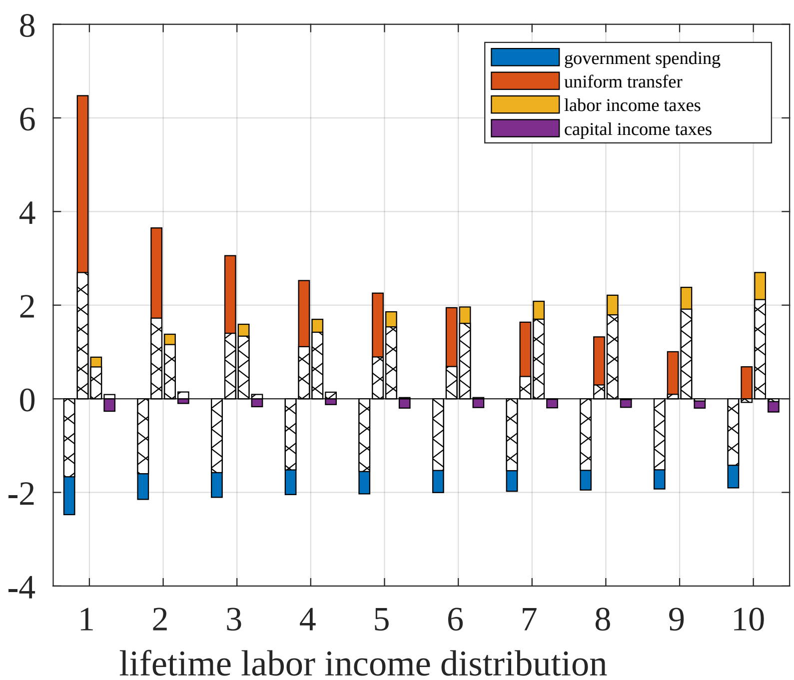
4.1.1 Welfare effects decomposition

Equation (17) shows that lifetime utility depends on individual consumption and labor supply choices along the life-cycle. Therefore we can decompose the overall welfare effects of the different policy options, as measured by the CEV, between their impact through consumption and the one through labor supply. In particular, we define the CEV_{cons} associated just to the change in consumption as the one solving the following equation:

$$W^b(i) = \sum_{j=1}^{J} \beta^{j-1} u \left[(1 + CEV^b_{cons}(i)) C^a(i,j), l^b(i,j) \right] \tag{19}$$

which differs from equation (18) as it fixes the sequence of labor supply to the final steady state choices for all agents. Figure (8) highlights in white the component due to consumption and compares it to the overall effect on the CEV. We can observe that the welfare impact occurring trough changes in consumption, be it negative or positive, represents, in absolute value, the largest component of total CEV under the government spending and for the personal income tax reduction redistribution schemes. On the contrary, under the uniform transfer scenario, agents face a strong incentive to cut working hours and enjoy more leisure. Moreover, the impact through a reduction in working time is the reason why such policy option offers a welfare gain to the agents belonging to the lifetime labor income top decile, who otherwise would suffer a loss due to a decline in consumption.

Figure 8: CEV_{cons} by income decile in white (%)



In general, the overall CEV reflects the joint change in the set of variables affecting the household lifetime utility maximization problem $(\tau^c, \{p_n\}_{n=2}^{6}, r, G, T, t_4, \tau^k, \xi)^{17}$, between the pre-tax and the

[17] The efficiency wage w is treated in the solution of our model as a numeraire.

Table 5: Definition of total CEV three components

New long-run value of:	CEV_{direct}	$CEV_{fiscal-policy}$	CEV_{GE}
carbon tax τ^c	✓	X	X
relevant fiscal parameter (G, T, t_4, τ^k)	X	✓	X
goods prices $\{p_n\}_{n=2}^{6}$	X	X	✓
real interest rate r	X	X	✓
public pension replacement rate ξ	X	X	✓

final stationary equilibria. As a consequence, we can alternatively breakdown the total CEV into the following three components:

$$CEV \approx CEV_{direct} + CEV_{fiscal-policy} + CEV_{GE} \tag{20}$$

where we define: (i) CEV_{direct} as the consumption equivalent variation that is needed to compensate individuals in the pre-tax initial stationary equilibrium to accept just the change in the carbon tax level, keeping the goods prices, the real interest rate and the fiscal parameters at their values before the policy change, as in a partial equilibrium setting; (ii) $CEV_{fiscal-policy}$ as the compensation that would make agents indifferent just with respect to the change in the relevant policy parameter of each revenue-recycling redistribution scheme (G, T, t_4 or τ^k depending on the policy scenario), leaving everything else unchanged; (iii) CEV_{GE} as the CEV component that can be traced back only to the changes in the goods prices (with the exception of the energy price), in the real interest rate and in the pension system replacement rate that arise in the new long-run equilibrium and that are due to general equilibrium forces.

In order to measure each term of the decomposition, we need first to derive the individual policy functions (for, in particular, consumption and labor supply at all ages) and the associated welfare emerging when only a subset of such vector of variables is set to the new long-run equilibrium. Table (5) summarizes which elements of the new steady state are accounted for in each of the three components.

The purpose of this exercise is to shed light on the relative importance of *direct* vs. *indirect* effects. Figures (9 - 11) display each component of equation (20) for the four redistribution schemes considered. CEV_{direct} is, by definition, constant across policy scenarios.

The direct impact of the change in the carbon tax τ^c from 0 to 10% on welfare, depicted in Figure (9) is, as expected, negative and larger for poorer households due to the limited ability to substitute energy with other goods in the consumption basket at lower income levels. Nonetheless, the direct impact of carbon taxation on welfare is substantially smaller of what is found once revenue-recycling and general equilibrium forces are accounted for, as a comparison with the overall CEV shown in Figure (3) reveals. This result suggests the importance of taking into consideration *indirect* effects when examining the welfare implications of environmental policies.

Turning the attention to the impact of the adjusting policy parameter (either G, T, t_4 or τ^k) in each revenue-recycling scheme in isolation, as measured by $CEV_{fiscal-policy}$ (Figure 10), we find a non-negative effect for all redistribution schemes and, more in detail, a progressive impact of the uniform transfer and of the reduction in the capital income tax rate. Conversely, we obtain a regressive

Figure 9: CEV_{direct} by income decile (%)

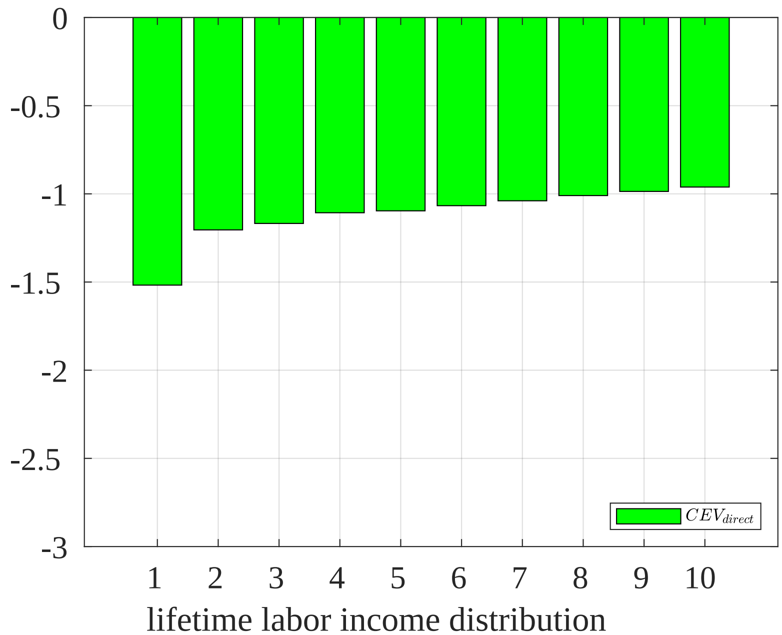


Figure 10: $CEV_{fiscal-policy}$ by income decile and across policy scenarios (%)

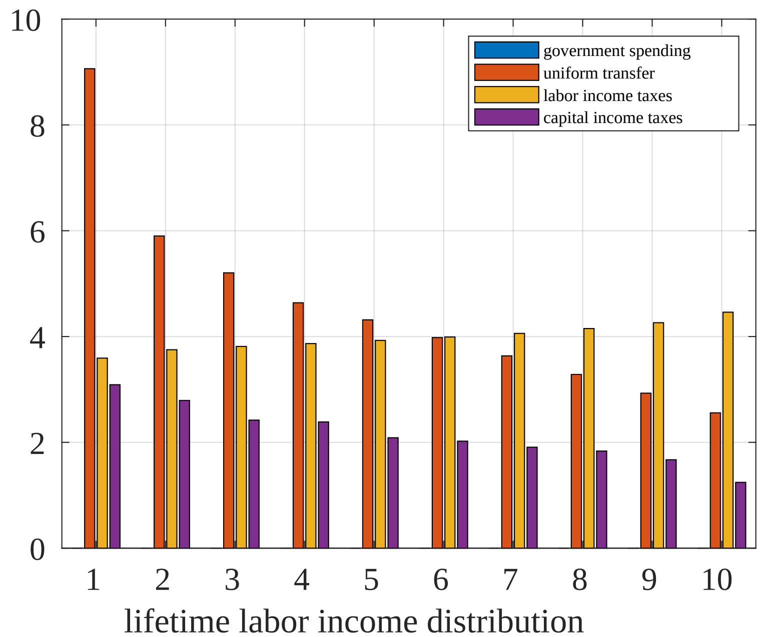


Figure 11: CEV_{GE} by income decile and across policy scenarios (%)

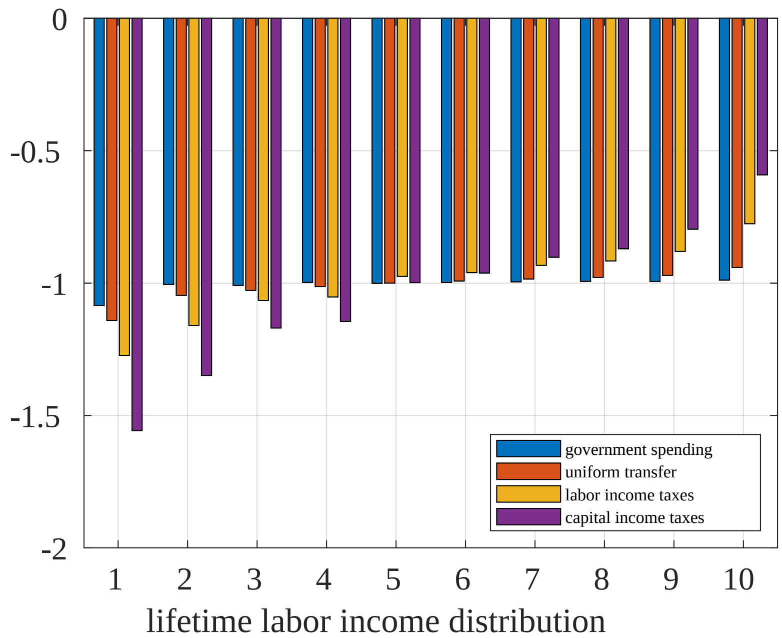
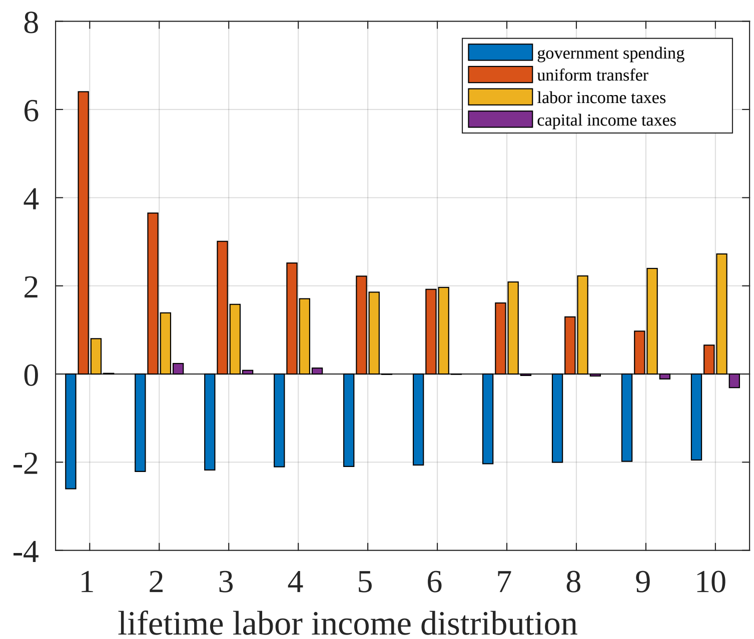


Figure 12: Sum of CEV_{direct}, $CEV_{fiscal-policy}$ and CEV_{GE} by income decile and across policy scenarios (%)



impact with the personal income tax rate cut, which overall yields a welfare gain that is larger than the one relative to the capital income tax reduction but smaller than the one obtainable with a uniform transfer. By construction, the scenario involving higher government spending has a zero impact on welfare as the increase in G has no direct impact on the household budget constraints. Overall, the uniform transfer policy option delivers the largest welfare effects. The markedly hetereogenous effects of revenue-recycling on welfare, both in terms of magnitude and from a distributional perspective, confirm that the way policy-makers decide to rebate the carbon tax revenue matters to determine who are the winners and the losers.

Finally, the inspection of Figure (11) reveals the negative impact of general equilibrium forces on welfare in all scenarios, which is centered around -1% of consumption on average. Moreover, moving from the policy experiment 1 to 4 we observe a growing burden for poorer households and a an increasing relief for the richer. We can therefore conclude that the effect of equilibrium prices for the revenue-recycling schemes falling under the *double-divided hypothesis* appear to have a more pronounced regressive profile than the others. Furthermore, it is worth noticing that the general equilibrium effect of the policy on welfare is almost as large as the direct impact, warranting once again the need of employing a general equilibrium model to analyze the distributional implications of carbon taxation.

The sum of the three components just defined does not necessarily correspond precisely to the overall CEV, as the decomposition in equation (20) does not account for the interaction terms among the different drivers. However, the sum of CEV_{direct}, $CEV_{fiscal-policy}$ and CEV_{GE} displayed in Figure (12), offers a good approximation of total CEV, as the comparison with Figure (3) indicates.

4.2 The transition

In this section, we analyze not only the welfare effects of the environmental policy on the generations born in the new long-run steady state, but also those on all the generations involved. For this goal, we examine the transition between stationary equilibria described in the previous section. As the model is dynamic, short term effects may generally deviate from long-term ones, and the burden of the green transition may not be evenly spread across generations. In line with the reasoning followed before, we compute the CEV for each cohort alive during the transition. Figures (13 - 16) show the CEV along the lifetime labor income distribution for all the generations born before and after the introduction of the carbon tax, where generation 0 is the one entering the labor markets (model age $j = 1$) when the policy is implemented, for each of the four different redistribution schemes. This sequence of CEV converges to that reported in Figure (3). Figures (17 - 20) display the adjustment of the relevant policy parameter needed to restore the government budget in each period.

The CEV plots suggest that the long-run welfare results derived above may in general not apply during the transition: in the case of the uniform transfer (Figure 14) the CEV for the richest agents belonging to the generations born before the introduction of the carbon tax is negative, while it turns positive for all the generations indexed ≥ 0, regardless of their position in the lifetime income distribution. When the rebating scheme consists of a reduction in progressive personal income taxes, the CEV is negative for all retired agents at the time of the introduction of the tax - the generations indexed < -37 - but becomes gradually positive for younger and relatively more skilled households

(Figure 15). On the contrary, while the generations born in the future stationary equilibrium suffer a welfare loss under the capital income taxes reduction scenario, the top lifetime income deciles of those indexed < -10 slightly gain in terms of welfare, as shown if Figure (16).

These last results can be rationalized looking at Figures (18), (19) and (20), which reveal that the adjusting policy parameters T, t_4 and τ^k are set, in the first stages of the transition, at values that differ from those taken in the long-run. So, the generations alive at time 0 obtain a uniform transfer, a reduction in personal income taxes or a capital income tax that are lower than the ones experienced by future generations. As an example, the after-tax return on capital, i.e. $(1 + r(1 - \tau^k))$, is much larger at the beginning of the transition than in the long-run. As a consequence, most of the agents that are retired when the policy is introduced enjoy a welfare gain, in contrast to the loss experienced by future generations.

At this point, we can compare the average CEV for the generations alive at the moment of the introduction of the environmental policy and the average CEV for the generations born in the new long-run stationary equilibrium, to check whether the welfare ranking among the alternative redistribution schemes considered is the same or not. In order to calculate the average CEV for the generations alive at time 0, we weight the different cohorts by their relative mass in the overall population. As Figure (21) highlights, the welfare ranking is not affected. The long-run welfare effects appear simply larger, as newborn generations experience the consequences of the carbon tax/rebating scheme combination for their entire lifespan and there are neither costs of reallocation of workers across sectors, nor search frictions generating unemployment in the short-run.

Figure 13: CEV by decile during the transition under the government spending scenario

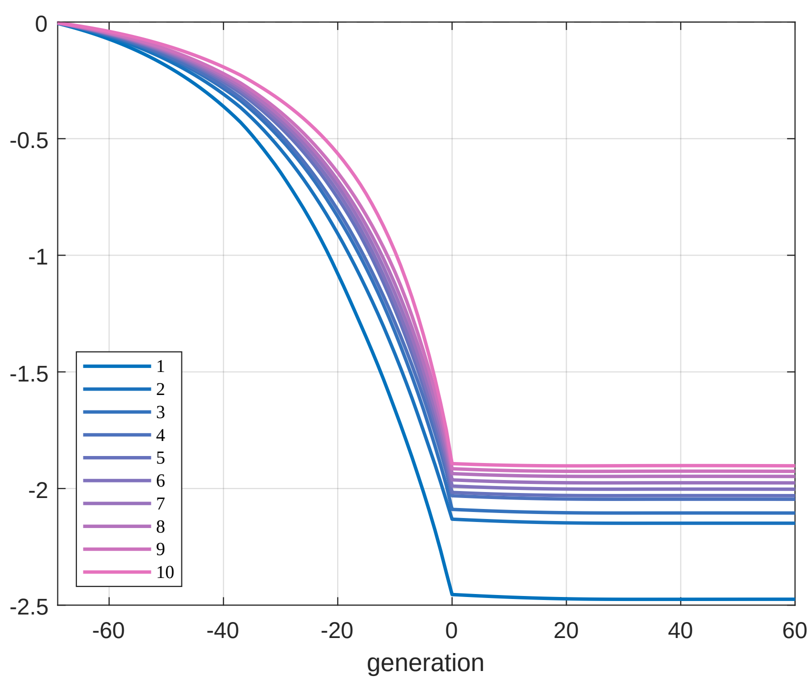


Figure 14: CEV by decile during the transition under the uniform transfer scenario

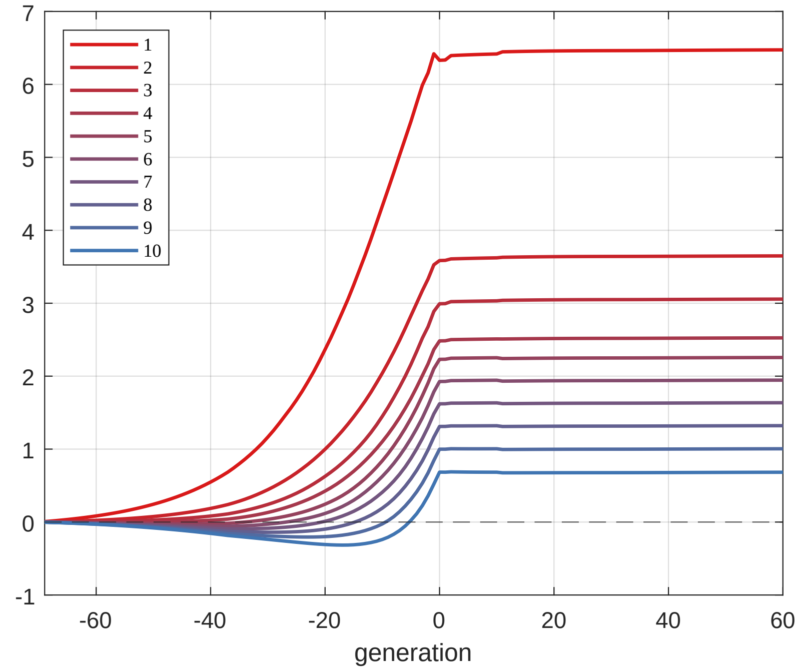


Figure 15: CEV by decile during the transition under the labor income tax reduction scenario

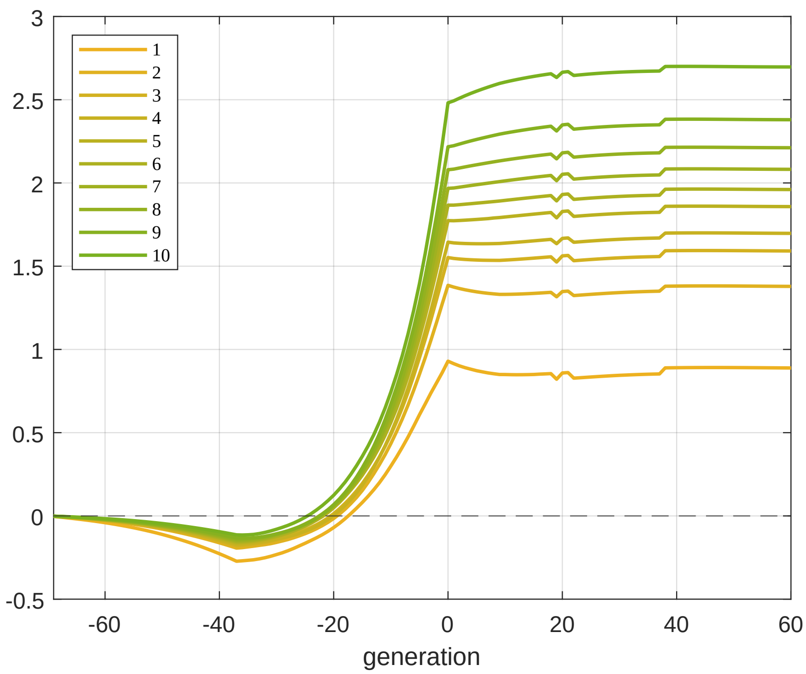


Figure 16: CEV by decile during the transition under the capital income tax reduction scenario

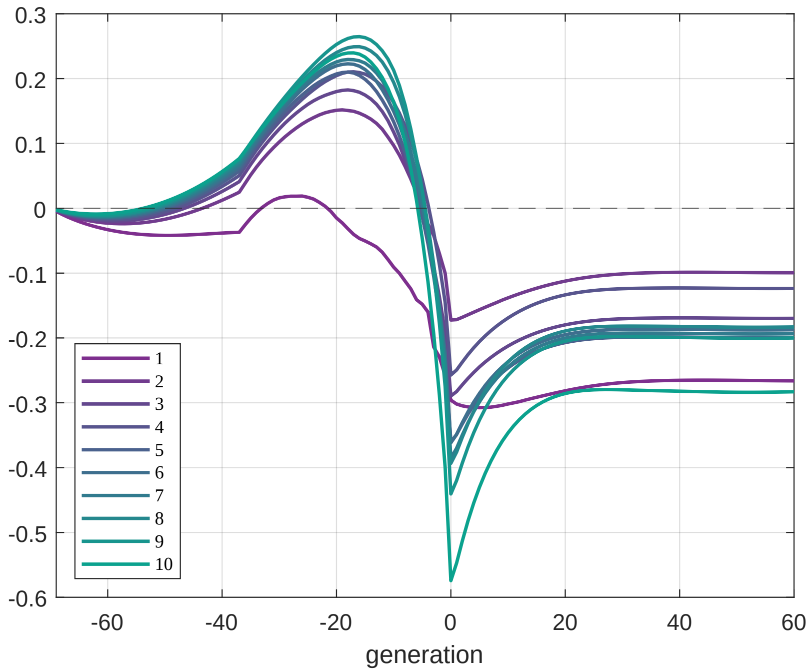


Figure 17: $\frac{\Delta G}{G}\%$ during the transition under the government spending scenario

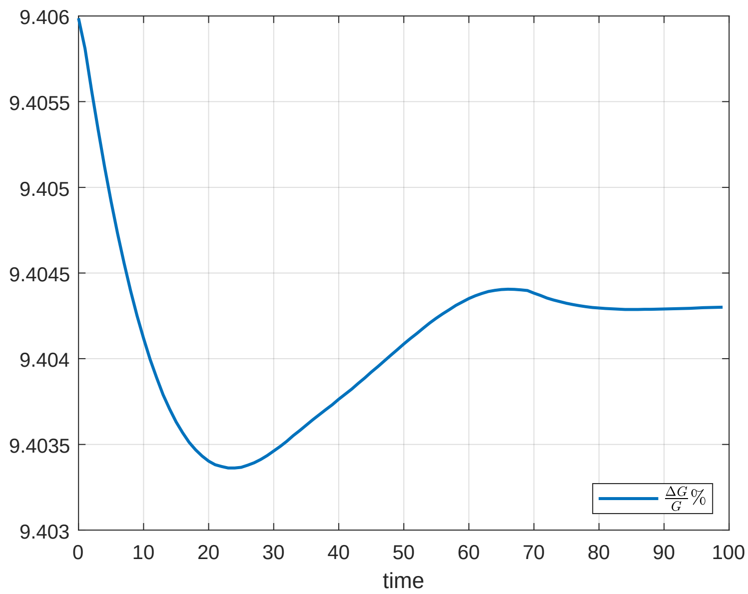


Figure 18: T during the transition under the uniform transfer scenario

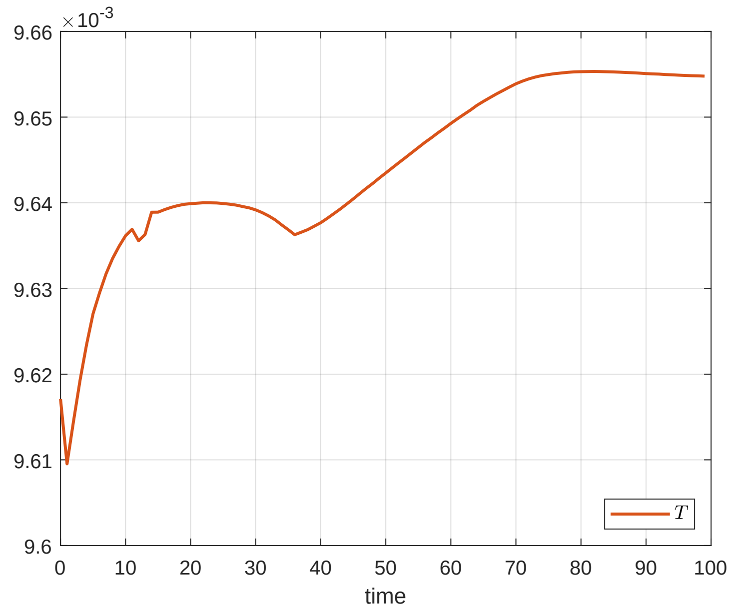


Figure 19: t_4 during the transition under the labor income tax reduction scenario

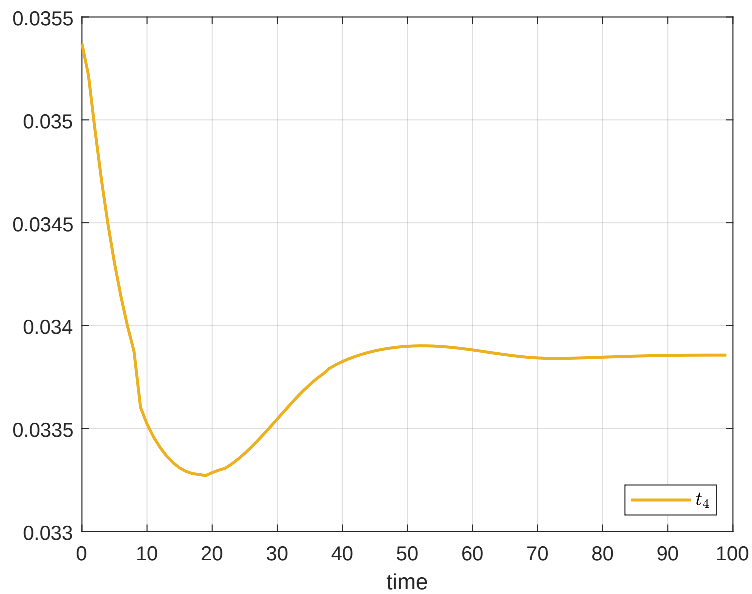


Figure 20: τ_k during the transition under the capital income tax reduction scenario

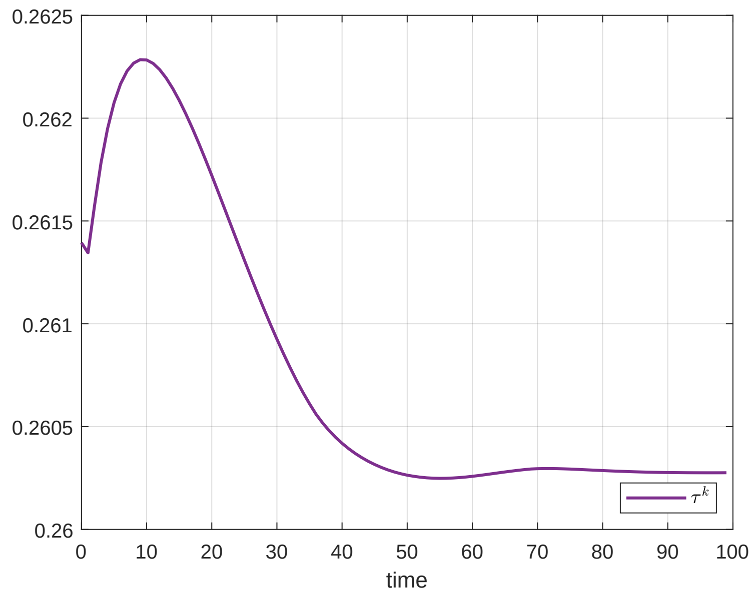
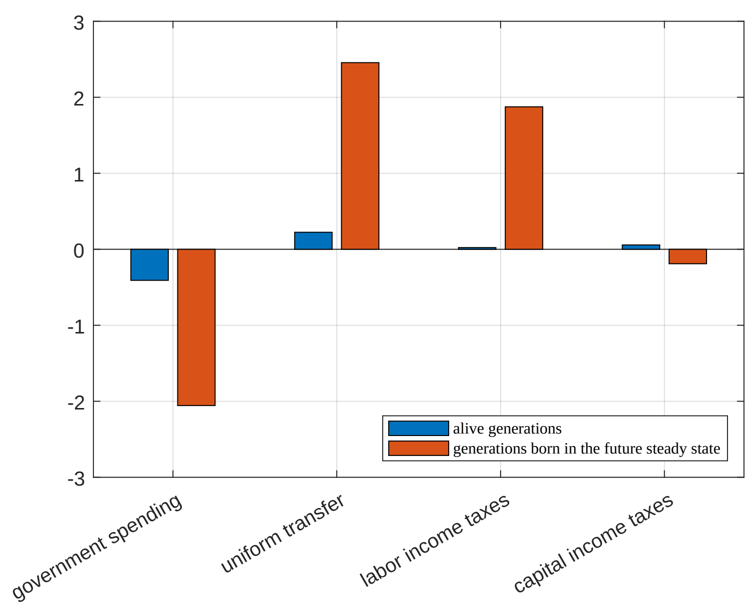


Figure 21: average CEV (%): alive vs. future generations



5 Conclusions

In this paper we build a sectoral general equilibrium OLG model, calibrated to the Italian economy, to measure the distributional consequences of introducing a carbon tax in Italy. In line with Fried et al. (2018), we model the carbon tax as a tax on energy consumption by households and firms, under the assumption that the whole Italian economy relies on a foreign exporter to satisfy its energy needs. We contribute to the existing literature by exploring the role of the heterogeneous impact of carbon taxes across different sectors. Accounting for (i) the differential substitutability between energy and the other factors of production; (ii) the differential energy intensity across sectors and (iii) input-output linkages; (iv) heterogeneous consumption patterns across households along the income distribution and (v) personal income tax progressivity allows us to simulate, through the lenses of our general equilibrium model, the realistic response to a permanent increase in the carbon tax rate.

In our quantitative experiments we simulate the effects a 10 percentage points tax rate increase under four alternative redistributive schemes. We find that the welfare consequences of environmental taxes greatly depend on the way carbon revenues are recycled. In a nutshell, our results indicate that it is feasible to promote an effective CO_2 reduction through a carbon tax without generating a welfare loss. This result holds in the long-run, both in the case of uniform transfer and in the case of a personal income tax cut. During the transition not all generations benefit from these two compensating schemes. With reference to the generations already alive at the moment of the policy introduction, those who bear the brunt are rich households under the uniform transfer scenario, and the very poor ones in the case of a reduction of the personal income tax. Indeed, under the former scheme, the nominal amount of the transfer is very small compared to the value of the consumption bundle purchased by rich households; similarly, the personal income tax reduction enjoyed by very poor households is negligible and quantitatively not sufficient to compensate them for the loss in purchasing power. Apart from these two extremes, we find that, on average, uniform transfers generate slightly higher welfare gains than a personal income tax cut, both for the generations alive at the moment of the introduction of the carbon tax and for future generations. This outcome would lead the policy-maker to prefer the uniform transfer rebating option from an equity point of view, given also its progressive impact. However, from an efficiency perspective, transfers generate a more pronounced slowdown in production across sectors (as agents work less) and a larger increase in prices. From this standpoint,the optimal revenue-recycling scheme would call for lower distortionary taxes.

References

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hémous, "The Environment and Directed Technical Change," *American Economic Review*, 2012, *102* (1), 131–166.

Andersson, Julius and Giles Atkinson, "The Distributional Effects of a Carbon Tax: the Role of Income Inequality," 2020, *5709* (378).

Auclert, Adrien, Bence Bardóczy, Matthew Rognlie, and Ludwig Straub, "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models," *Econometrica*, 2021, *89* (5), 2375–2408.

Baccianti, Claudio, "Estimation of Sectoral Elasticities of Substitution Along the International Technology Frontier," *SSRN Electronic Journal*, 2013, (13).

Barrage, Lint, "Optimal Dynamic Carbon Taxes in a Climate-Economy Model with Distortionary Fiscal Policy," *American Historical Review*, 2019, *124* (2), 1–39.

Berry, Audrey, "The Distributional Effects of a Carbon Tax and its Impact on Fuel Poverty: a Microsimulation Study in the French Context," *Energy Policy*, 2019, *124* (October 2018), 81–94.

Bovenberg, A. Lans and Lawrence H. Goulder, "Optimal Environmental Taxation in the Presence of Other Taxes: General- Equilibrium Analyses," *American Economic Review*, 1996, *86* (4), 985–1000.

Cai, Mattia and Toon Vandyck, "Bridging between Economy-wide Activity and Household-level Consumption Data: Matrices for European Countries," *Data in Brief*, 2020, (30).

Callan, Tim, Sean Lyons, Susan Scott, Richard S.J. Tol, and Stefano Verde, "The Distributional Implications of a Carbon Tax in Ireland," *Energy Policy*, 2009, *37* (2), 407–412.

Carroll, Christopher D., "The Method of Endogenous Gridpoints for Solving Dynamic Stochastic Optimization Problems," *Economics Letters*, 2006, *91* (3), 312–320.

Chiroleu-Assouline, Mireille and Mouez Fodha, "From Regressive Pollution Taxes to Progressive Environmental Tax Reforms," *European Economic Review*, 2014, *69* (November 2008), 126–142.

Curci, Nicola, Marco Savegnago, and Marika Cioffi, "BIMic: The Bank of Italy Microsimulation Model for the Italian Tax and Benefit System," *Bank of Italy Occasional Paper*, September 2017, (394).

Dorband, Ira Irina, Michael Jakob, Matthias Kalkuhl, and Jan Christoph Steckel, "Poverty and Distributional Effects of Carbon Pricing in Low- and Middle-Income Countries – A Global Comparative Analysis," *World Development*, 2019, *115*, 246–257.

Douenne, Thomas, "The Vertical and Horizontal Distributive Effects of Energy Taxes: A Case Study of a French Policy," *The Energy Journal*, 2020, *41* (3), 1–43.

Faiella, Ivan and Luciano Lavecchia, "Households' Energy Demand and the Effects of Carbon Pricing in Italy," *SSRN Electronic Journal*, 2021, pp. 1–38.

Farrell, Niall, "What Factors Drive Inequalities in Carbon Tax Incidence? Decomposing Socioeconomic Inequalities in Carbon Tax Incidence in Ireland," *Ecological Economics*, 2017, *142*, 31–45.

Feindt, Simon, Ulrike Kornek, José M. Labeaga, Thomas Sterner, and Hauke Ward, "Understanding Regressivity: Challenges and Opportunities of European Carbon Pricing," *Energy Economics*, 2021, *103*.

Feng, Kuishuang, Klaus Hubacek, Dabo Guan, Monica Contestabile, Jan Minx, and John Barrett, "Distributional Effects of Climate Change Taxation: the Case of the UK," *Environmental Science and Technology*, 2010, *44* (10), 3670–3676.

Fried, Stephie, Kevin Novan, and William B. Peterman, "The Distributional Effects of a Carbon Tax on Current and Future Generations," *Review of Economic Dynamics*, 2018, *30* (2018), 30–46.

_ , _ , and William B Peterman, "How Should Carbon Tax Revenue Be Recycled?," *Mimeo*, 2020, pp. 1–28.

Fullerton, Don and Garth Heutel, "The General Equilibrium Incidence of Environmental Taxes," *Journal of Public Economics*, 2007, *91*, 571–591.

Geary, Roy C., "A Note on "A Constant-Utility Index of the Cost of Living"," *The Review of Economic Studies*, 1950, *18* (1), 65–66.

Golosov, Mikhail, John Hassler, Per Krusell, and Aleh Tsyvinski, "Optimal Taxes on Fossil Fuel in General Equilibrium," *Econometrica*, 2014, *82* (1), 41–88.

Gonne, Nicolas, "Assessing the Impact of Carbon Taxation on Sectoral Competitiveness: the Case of Belgium," *Reflets et Perspectives de la Vie Economique*, 2016, *55* (2), 27–40.

Gonzalez, Fidel, "Distributional Effects of Carbon Taxes: the Case of Mexico," *Energy Economics*, 2012, *34* (6), 2102–2115.

Goto, Noriyuki, "Macroeconomic and Sectoral Impacts of Carbon Taxation. A Case for the Japanese Economy," *Energy Economics*, 1995, *17* (4), 277–292.

Gouveia, Miguel and Robert P Strauss, "Effective Federal Individual Income Tax Functions: an Exploratory Empirical Analysis," *National Tax Journal*, 1994, *47* (2), 317–339.

Hassler, John, Per Krusell, and Conny Olovsson, "Directed Technical Change as a Response to Natural Resource Scarcity," *Journal of Political Economy*, 2021, *129* (11), 3039–3072.

Känzig, Diego R., "The Unequal Economic Consequences of Carbon Pricing," *Working Paper*, 2021.

Kaplan, Greg, "Inequality and the life cycle," *Quantitative Economics*, 2012, *3*, 471–525.

Labandeira, Xavier and José M. Labeaga, "Combining Input-Output Analysis and Micro-Simulation to Assess the Effects of Carbon Taxation on Spanish Households," *Fiscal Studies*, 1999, *20* (3), 305–320.

Li, Zi, Baijun Wu, Danyang Wang, and Maogang Tang, "Government mandatory energy-biased technological progress and enterprises' environmental performance: Evidence from a quasi-natural experiment of cleaner production standards in China," *Energy Policy*, 2022, (22).

MASE, "La Situazione Energetica Nazionale nel 2022," *Ministero dell'Ambiente e della Sicurezza Energetica*, 2023, *Luglio*, 1–131.

Metcalf, Gilbert E., "A Distributional Analysis of Green Tax Reforms," *National Tax Journal*, 1999, *Lll* (4), 655–681.

Nordhaus, William, "Integrated economic and climate modeling," *Handbook of Computable General Equilibrium Modeling*, 2013, *1*, 1069–1131.

_ , "Climate change: The ultimate challenge for economics," *American Economic Review*, 2019, *109* (6), 1991–2014.

Ohlendorf, Nils, Michael Jakob, Jan Christoph Minx, Carsten Schröder, and Jan Christoph Steckel, *Distributional Impacts of Carbon Pricing: A Meta-Analysis*, Vol. 78, Springer Netherlands, 2021.

Paoli, Maria Chiara and Rick Van der Ploeg, "Recycling Revenue to Improve Political Feasibility of Carbon Pricing in the UK," *https://voxeu.org/article/recycling-revenue-improve-political-feasibility-carbon-pricing-uk*, 2021.

Renner, Sebastian, "Poverty and Distributional Effects of a Carbon Tax in Mexico," *Energy Policy*, 2018, *112*, 98–110.

Ríos-Rull, José-Víctor, "Life-Cycle Economies and Aggregate Fluctuations," *The Review of Economic Studies*, 1996, *63* (3), 465–489.

Sterner, Thomas, "Distributional Effects of Taxing Transport Fuel," *Energy Policy*, 2012, *41*, 75–83.

Tasso, Martino, "Do Details Matter? An Analysis of Italian Personal Income Tax," *Temi di Discussione n. 1301, Banca d'Italia Working Papers*, 2020, (November), 1–33.

Tol, Richard S.J., Thomas E. Downing, Onno J. Kuik, and Joel B. Smith, "Distributional Aspects of Climate Change Impacts," *OECD Workshop, Benefits of Climate Policy: Improving Information for Policy Makers*, 2003, p. 32.

Wang, Qian Wang, Klaus Hubacek, Kuishuang Feng, Yi-Ming Wei, and Qiao-Mei Liang, "Distributional Effects of Carbon Taxation," *Applied Energy*, 2016, (184).

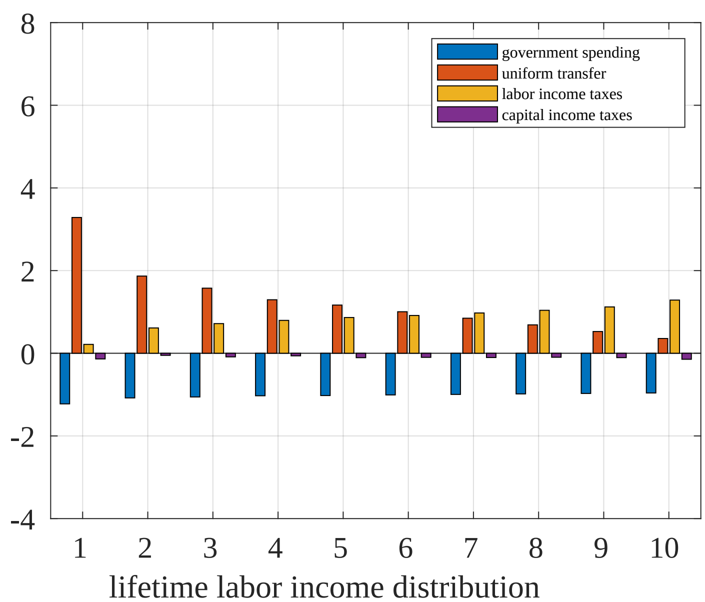
West, Sarah E. and Roberton C. Williams, "Estimates From a Consumer Demand System," *Distributional Effects of Environmental and Energy Policy*, 2018, (September), 117–140.

Appendices

A Weaker pass-through

In this section, we assume that the pass-through of the carbon tax to the energy price is smaller than in the benchmark scenario. This is a reduced-form shortcut to model the existence of adaptation strategies by firms and households, as well as more intense diffusion of renewables. In practice, the possibility for them to switch to greener sources of energy translates to an energy price increase of 5% rather than 10% in the long-run stationary equilibrium. As expected, the welfare effects result to be quantitatively smaller, but qualitatively very similar to the ones derived in the main text.

Figure 22: CEV by income decile (%)



B Solution method

The solution of the stationary equilibrium and transition dynamics of the model requires standard numerical methods, given the large systems of non-linear equations. A standard algorithm is implemented involving the following iterative procedure:

1. guess a set of endogenous variables, including the real interest rate r, the labor demand of each sector, the public pension replacement rate ξ ensuring the balance between total contributions and total benefits, and the adjusting fiscal policy parameter in the simulation (the efficiency wage w is set as numeraire);

2. given the energy price p_1, the real interest rate r, the efficiency wage w and the labor demand of each sector, solve for the prices p_n, output $Y(n)$ capital demand $K(n)$, energy demand $E(n)$ and intermediate inputs demand $Y^d(s,n)$ for each sector, such that the firms' first order conditions are satisfied;

3. given prices p_n, the efficiency wage w, the public pension replacement rate ξ, solve for the households' lifetime utility maximization problem to retrieve the optimal consumption (of each good), savings and labor supply for all points in the state space;

4. simulate the lifetime optimal behavior of 3000 households, drawing the idiosyncratic shocks from the relative distributions;

5. aggregate individual choices to determine the ex-post level of aggregate capital supply, aggregate consumption for each good, labor income taxation total revenue, total capital income total revenue;

6. verify whether the goods markets and the capital market clear as well as whether the government budget and public pension budget are balanced;

7. if the previous equilibrium conditions are not met, update the guess for the next iteration and repeat all the steps until convergence.

The updating scheme for the steady-state solution relies on a Newton-Raphson method, which involves computing the jacobian of the system of non-linear equations having as unknown variables the real interest rate r, the labor demand of each sector, the public pension replacement rate ξ and the adjusting fiscal policy parameter. The jacobian evaluated at the new long-run stationary equilibrium of each policy experiment is then employed to solve for the transition, applying the method described in Auclert et al. (2021) for permanent shocks. Such method ensures a quick convergence to the solution. Solving for the entire perfect foresight transition path requires choosing a sufficiently large number of transition periods to ensure the convergence to a new stationary equilibrium. We solve the transition forward, which means that we solve the lifetime utility maximization problem for each generation involved in the transition, taking into account the evolution of prices along her lifetime, starting from the generation that reaches age J in the first period of the transition.

A crucial step of the procedure is the one where we compute households' optimal path of consumption, labor supply and savings over the life cycle, in the presence of borrowing constraints. For this task, we rely on the endogenous grid method by Carroll (2006).

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GUGLIELMINETTI E., M. LOBERTO and A. MISTRETTA, *The impact of COVID-19 on the European short-term rental market,* Empirica, v. 50, 3, pp. 585-623, **WP 1379 (July 2022).**

LILLA F., *Volatility bursts: a discrete-time option model with multiple volatility components,* Journal of Financial Econometrics, v. 21, 3, pp. 678-713, **WP 1336 (June 2021).**

LOBERTO M., *Foreclosures and house prices,* Italian Economic Journal / Rivista italiana degli economisti, v. 9, 1, pp. 397-424, **WP 1325 (March 2021).**

LOMBARDI M. J., M. RIGGI and E. VIVIANO, *Worker's bargaining power and the Phillips curve: a micro-macro analysis, and wages,* Journal of the European Economic Association, v. 21, 5, pp. 1905–1943, **WP 1302 (November 2020).**

MODENA F., S. PEREDA-FERNANDEZ and G. M. TANZI, *On the design of grant assignment rules,* Politica economica/Journal of Economic Policy, v. 1/2023, pp. 3-40, **WP 1307 (December 2020).**

NERI S., *Long-term inflation expectations and monetary policy in the Euro Area before the pandemic*, European Economic Review, v. 154, Article 104426, **WP 1357 (December 2021).**

ORAME A., *Bank lending and the European debt crisis: evidence from a new survey*, International Journal of Central Banking, v. 19, 1, pp. 243-300, **WP 1279 (June 2020).**

RIZZICA L., G. ROMA and G. ROVIGATTI, *The effects of shop opening hours deregulation: evidence from Italy,* The Journal of Law and Economics, v. 66, 1, pp. 21-52, **WP 1281 (June 2020).**

TANZI G. M., *Scars of youth non-employment and labour market conditions,* Italian Economic Journal / Rivista italiana degli economisti, v. 9, 2, pp. 475-499, **WP 1312 (December 2020).**

2024

BALTRUNAITE A. and E. KARMAZIENE, *Fast tracks to boardrooms: director supply and board appointments,* Journal of Corporate Finance, v. 88, Article 102642, **WP 1278 (June 2020).**

BENCHIMOL J. and L. PALUMBO, *Sanctions and Russian Online Prices,* Journal of Economic Behavior & Organization, v. 225, pp. 483-521, **WP 1468 (October 2024).**

BRANZOLI N., R. GALLO, A. ILARI and D. PORTIOLI, *Central banks' corporate asset purchase programmes and risk-taking by bond funds in the aftermath of market stress,* Journal of Financial Stability, v. 72, Article 101261, **WP 1404 (March 2023).**

BRANZOLI N., E. RAINONE and I. SUPINO, *The role of banks' technology adoption in credit markets during the pandemic,* Journal of Financial Stability, v. 71, Article 101230, **WP 1406 (March 2023).**

BUONO I, F. CORNELI and E. DI STEFANO, *Capital inflows to emerging countries and their sensitivity to the global financial cycle,* International Finance, v. 27,2, pp. 17-34, **WP 1262 (February 2020).**

DEL PRETE S, G. PAPINI and M. TONELLO, *Gender quotas, board diversity and spillover effects. Evidence from Italian banks,* Journal of Economic Behavior & Organization, v. 221, pp. 148-173, **WP 1395 (December 2022).**

DE MARCHI R. and A. MORO, *Forecasting fiscal crises in emerging markets and low-income countries with machine learning models,* Open Economies Review. v. 35, 1, pp. 189-213, **WP 1405 (March 2023).**

FERRARI A. and V. NISPI LANDI, *Whatever it takes to save the planet? Central banks and unconventional green policy,* Macroeconomic Dynamics, v. 28, 2, pp. 299-324, **WP 1320 (February 2021).**

FLACCADORO M., *Exchange rate pass-through in small, open, commodity-exporting economies: lessons from Canada,* Journal of International Economics, v. 148, Article 103885, **WP 1368 (May 2022).**

GAUTIER E., C. CONFLITTI, R. FABER, B. FABO, L. FADEJEVA, V. JOUVANCEAU, J.-O. MENZ, T. MESSNER, P. PETROULAS, P. ROLDAN-BLANCO, F. RUMLER, S. SANTORO, E. WIELAND and H. ZIMMER, *New facts on consumer price rigidity in the euro area,* American Economic Journal: Macroeconomics, v. 16, 4, pp. 386-431, **WP 1375 (July 2022).**

LATTANZIO S., *Schools and the transmission of Sars-Cov-2: evidence from Italy,* Economics & Human Biology, v. 52, Article 101342, **WP 1453 (February 2023).**

MORO A. and V. NISPI LANDI, *The external financial spillovers of CBDCs,* Journal of Economic Dynamics and Control, v. 159, Article 104801, **WP 1416 (July 2023).**

PORRECA E. and A. ROSOLIA, *Immigration and unemployment. Do natives get it right?,* Journal of Economic Behavior & Organization, v. 225, pp. 522–540, **WP 1273 (April 2020).**

RAINONE E., *Real-time identification and high frequency analysis of deposits outflows,* Journal of Financial Econometrics, v. 22, 4, pp. 868–907, **WP 1319 (December 2017).**

ZAGHINI A., *Unconventional Green,* Journal of Corporate Finance, v. 85, Article 102556, **WP 1453 (April 2024).**

FORTHCOMING

BALTRUNAITE A., M. CANNELLA, S. MOCETTI and G. ROMA, *Board composition and performance of state-owned enterprises: quasi experimental evidence,* The Journal of Law, Economics, and Organization, **WP 1328 (April 2021).**

BENVENUTI M. and S. DEL PRETE, *The evolution of banking competition in italian credit markets using a profit elasticity approach,* Italian Economic Journal / Rivista italiana degli economisti, **WP 1237 (October 2019).**

CIANI E., A. GROMPONE and E. OLIVIERI, *Jobs for the long-term unemployed: place-based policies in depressed areas,* Italian Economic Journal / Rivista italiana degli economisti, **WP 1249 (November 2019).**

CUCINIELLO V. and N. DI IASIO, *Determinants of the credit cycle: a flow analysis of the extensive margin,* Journal of Money, Credit and Banking, **WP 1266 (March 2020).**

CUCINIELLO V., C. MICHELACCI and L. PACIELLO, *subsidizing business entry in competitive credit markets,* Journal of Political Economy, **WP 1424 (October 2023).**

FLACCADORO M., *Exchange rate pass-through in small, open, commodity-exporting economies: lessons from Canada,* Journal of International Economics, **WP 1365 (April 2022).**

LOSCHIAVO D., F. TULLIO and A. DI SALVATORE, *Measuring households' financial fragilities: an analysis at the intersection of income, financial wealth, and debt,* Review of Income and Wealth, **WP 1452 (April 2024).**

MICHELANGELI V. and E. VIVIANO, *Can internet banking affect households' participation in financial markets and financial awarness?,* Journal of Money, Credit and Banking, **WP 1329 (April 2021).**

MISTRETTA A., *Synchronization vs transmission: the effect of the German slowdown on the Italian business cycle,* International Journal of Central Banking, **WP 1346 (October 2021).**

MORO A., *Optimal policies in a small open economy with an environmental externality and shallow foreign exchange markets,* Portuguese Economic Journal, **WP 1348 (October 2021).**

RAINONE E., *Reservation rates in interbank money markets,* Journal of Money, Credit and Banking, **WP 1160 (February 2021).**

ROPELE T., Y. GORODNICHENKO and O. COIBION, *Inflation expectations and misallocation of resources: evidence from Italy,* American Economic Review: Insights, **WP 1437 (December 2023).**

ROSOLIA A., *Do firms act on their inflation expectations? Another look at Italian firms,* Journal of Political Economy Macroeconomics, **WP 1353 (October 2021).**