Supplementary Information

Alternatives to Green Growth: Low-Carbon Transition Needs Social Equity

André Cieplinski, Simone D'Alessandro*,
Tiziano Distefano and Kristofer Dittmer

* Simone D'Alessandro. E-mail: simone.dalessandro@unipi.it

Contents

List of Figures

List of Tables

1 The EUROGREEN Model

1.1 Data

The EUROGREEN model required a vast effort in collecting, merging, analyzing, and synthesizing the necessary amount of data to calibrate the parameters, to underpin several behavioural assumption, and to verify the robustness of the simulated results. For this reason, we gather data from alternative databases, depending on availability. In particular:

- *World Input-Output Database* ($WIOD$),[1] allowed us to construct the productive sector architecture. It is based on the NACE Rev.2 classification.[2] Data are provided from 2000 to 2014 at current euro price (i.e., nominal values).
- *Eurostat*: provides annual energy balances (https://ec.europa.eu/eurostat/web/energy/data/energy-balances) from which we recovered the annual Total Primary Energy Supply ($TPES$), by industry, and the distribution and composition of sources used for the energy and electricity production. Additionally, it provides data on greenhouse gas emissions by (the NACE Rev.2) sectors (http://appsso.eurostat.ec.europa.eu/nui/show.do?lang=en&dataset=env_air_gge). When information on energy or air pollution were not available, we integrated the gaps with data from the International Energy Agency (IEA, https://www.iea.org/policiesandmeasures/pams/france/). We also obtained data on Government expenditure by function from Eurostat's *COFOG* database (https://ec.europa.eu/eurostat/cache/infographs/cofog/)
- *EU-Klems Project* (http://www.euklems.net/project_site.html): collects data on labour composition, hourly wages, and working hours, by skill and industry. Data on labour force supply were collected from Eurostat.
- *OECD.Stat*: provides data on social benefits and on France taxation system (http://www.oecd.org/social/benefits-and-wages.htm).
- the French national statistics office INSEE[3] reports demographic data, completed with Eurostat when necessary.

In what follows we describe the dynamic equations behind each build block, where each period represents a solar year. In addition to the supplementary material, the full list of equations and the causal links between all the variables of the model are available at: https://people.unipi.it/simone_dalessandro/eurogreen-model/. In equations, the time index t denotes the current year, $t-1$ the immediately preceding period, $t-2$ the one before that, and so on. The first simulated period is the year 2014. 'Nominal' variables are expressed at current prices, in contrast to 'real' variables which represent monetary values corrected for changes in price, or the number of physical objects produced or consumed.

1.2 Population dynamic, ageing, and education

There are four age groups: I. 0–14, II. 15–44, III. 45–64, and IV. 65 years onward. We assume that all persons in employment belong to groups II and III.[4] The population model includes specific assumptions about: mortality rate (α^-),[5] fertility rate (α^+), inter-cohorts flow rate (ϱ), reproductive lifetime (RL), and life expectancy (LE). These parameters are all treated as exogenous throughout the simulations, hence, for $n \epsilon \{I, II, III, IV\}$, the change in population of cohort n

[1] We opted for the last freely-available version "Release 2016", see http://www.wiod.org/database/wiots16.

[2] See http://ec.europa.eu/eurostat/ramon/nomenclatures.

[3] See https://www.insee.fr/en/accueil.

[4] Indeed, only the 4.4% of the resident population aged 65–74 formed part of the labour force in 2014 (Eurostat LFS).

[5] Note that the birth rate could be linked to women education; however, for now we take it an exogenous constant over all the simulation time window.

from year $t-1$ to year t ($\Delta Pop_{n,t}$) is described by the following equation:

$$\Delta Pop_{n,t} = (Pop_{II,t} + Pop_{III,t})\frac{0.5 \cdot \alpha^{+}}{RL} - Pop_{n,t-1} \cdot (\varrho_n^{-} + \alpha_n^{-}) + \varrho_n^{+} Pop_{n-1,t-1} \quad (1)$$

where $\alpha^{+} = 2.11$ constant (only for $n = I$), $RL = 30$ is the number of years women can be fertile, ϱ is a fraction of survived people who goes to/from (ϱ_n^{-} and ϱ_n^{+}, respectively) the next/previous population cohort. The mortality rate depends on the lifetime expectancy (set to 80 years in the model) with the following values per cohort: $\alpha_I^{-} = 0.001$, $\alpha_{II}^{-} = 0.0005$, $\alpha_{III}^{-} = 0.00171$, and $\alpha_{IV}^{-} = 0.04$.

The population aged 15 years or over is divided into three groups (or socio-economic strata), based on the level of educational qualifications: low-skilled, medium-skilled, and high-skilled. The low-skilled group has lower secondary education or below, corresponding to levels 0-2 of the ISCED 2011 classification. The medium-skilled group has upper secondary or post-secondary non-tertiary education (ISCED 3 and 4). Finally, the high-skilled group has tertiary education (ISCED 5-8).[6]

The wide scope of EUROGREEN calls for some simplifications of the concepts of population and employment. Models addressing the relationship between output and employment generally use the domestic concept of employment, defined as "employment in resident production units irrespective of the place of residence of the employed person". In contrast, a model of the budgetary implications of the introduction of a basic income given to all legal residents of a country would use the national concept of population and employment, as this refers to permanent residents only.

Table 1: Population groups and skill distribution.

2014	*L* (%)	*M* (%)	*H* (%)	*L*	*M*	*H*	*Total*
Pop. 0+	-	-	-	-	-	-	*66,456*
Pop. 15 or more (18+)	33.5	40.2	26.3	18118	21729	14263	54,110 (51,673)
Pop. 20+	30.7	40.9	28.4	15408	20469	14211	50,087
Pop. 65+	57.5	27.9	14.6	7001	3427	1806	12,234
Work age 15–64 (18–64)	26.6	43.7	29.7	11117	18302	12457	41,876 (39,439)
Employed	17.2	45.0	37.8	4723	12307	10343	27,373
Unemployed	44.1	41.3	14.6	6394	5995	2114	14503

Skill levels of the resident population are divided in low (L), medium (M), and high (H) educational attainment. Values by age group and employment status are in thousands (1,000) of units. Source: Own calculations based on Eurostat.

Table 9 report data on the Labour Force Supply (LFS), composed by employed and unemployed workers divided by level of educational attainment. To deal with data inconsistencies, we take employment in persons from the national accounts as given. We assume that the variation in the labour force participation rate ($\Delta LFPR$) is led by the unemployment dynamic (Δu), to say. The dynamics of labour supply and its composition between skills is described in greater

[6] Regarding the educational attainment of the elderly, the Labour Force Survey does not include the population aged 75 or over. Therefore, to obtain a more complete picture for 2014, we use responses of the 70-74 cohort from 2009, 2004, and 1999 (applying the shares of the 70-74 group of 1999, corresponding to the 85-89 group of 2014, also to the 90+ group of 2014). We make an adjustment for correlations between life expectancy and skill by comparing the skill-shares of the 65-69 cohort of 2009 with the 70-74 cohort of 2014 and applying the implied differential mortality rates once to each of the pre-2014 response groups. This amount to assuming that there are no skill-based differences in mortality rates beyond 80.

detail in chapter 1.12.

1.3 Input–Output

In the model, as in the real-world economy, productive sectors are interrelated through a web of flows of intermediate goods and services. The so-called 'technical coefficients', i.e., the amount of material inputs required per unit of output (both measured in basic prices) in each sector, are calculated for 2014 using the National Input-Output Table (NIOT) of France from the World Input-Output Database (WIOD, Release 2016; see Timmer et al., 2015). In terms of product flows between industries, this table is more accurate than the national accounts' input-output tables, which are of the product-product or industry-industry sort, i.e., square matrices. In contrast, WIOD tables are industry-based but adjusted to correspond better with product-based international trade data. Moreover, WIOD is more accurate in terms of the uses of imports (Dietzenbacher et al., 2013).[7]

The aggregation from NACE to our ten industries is summarized in Table 2.

We impose some simplifications to aggregate the sectors as provided by WIOD in those applied in the EUROGREEN model. The construction and real estate services industries are aggregated. No special account is taken of the large share of this industry's activity represented by the imputed rents of owner-occupied dwellings. Nevertheless, the output imputed to this activity is shown in Table 3. Imputed rents are the main element of the output for own final use of households. At 168,078 million euros, they are also the major part of the output of the real estate sector (where imputed rents are registered in subdivision L68A), which summed up 300,395 million euros in 2014.

For sake of simplicity, the total private final consumption (f_{HH}) is given by the sumup final consumption expenditure of households and of non-profit institutions serving households (NPISH). Moreover, whenever the final government expenditure was less than 10% of f_{HH}, it was addedd to f_{HH} itself. The same rule was applied to imports, so that they were shifted to domestic production (except for non-financial services due to the large size of its imports in absolute terms). The largest shift affected sector E, with a 7.7% imports-to-domestic-output ratio (also shifted are D, F, K, L, O, P, and Q). To keep domestic industry outputs unchanged, exports are reduced by equivalent amounts. When this would make exports negative (sectors F and L), the amount is instead subtracted from GFCF. This assumption means that the model economy's degree of openness (i.e., exports plus imports as share of GDP) will be somewhat smaller than the actual value for 2014. At 567,278 million, model imports are 2.9% lower than the real-world figure (584,372 million), and exports are 2.5% lower at 557,507 million (571,814 million).

Our model follows the Leontief and the post-Keynesian traditions,[8] by acknowledging that the economy is *demand-driven* and that industries are involved in inter-industry trade (both at national and international level). We assume that each sector uses labour, capital, and energy as productive factors. In an *open economy* each sector i faces the international market and, given the stability over time, we assumed that each sector imports a constant fraction (m_i) of its total output from the rest of the world. The international trade depend on the ratio between domestic and foreign prices, as described in the following section.

We define the total output[9] of each industry (i) as:

$$y_i = f_i + \sum_j Z_{i,j} + \chi_i \tag{2}$$

where f_i is the domestic final demand which is given by the sum of gross fixed capital formation, private and govern-

[7] However, probably due to these corrections, aggregate output of 2014 is 0.6% lower in the NIOT than in the national accounts, and output varies at the industry level from 4.4% lower (sector I) to 4.3% higher (sector E), though the discrepancy is generally around 1%.

[8] See Miller and Blair (2001) and Lavoie (2014) for a description.

[9] Because population dynamics are exogenous, output is not purely demand-determined.

Table 2: NIOT Classification in EUROGREEN

Num.	**Name**	*NACE Rev. 2 code*	**NACE Rev. 2 description**
1	**Agriculture**	*A*	Agriculture, forestry and fishing
2	**Mining**	*B*	Mining and quarrying
3	**Fossil Fuels**	*C19*	Manufacture of coke and refined petroleum products
4	**Manufacturing**	*C (excl. C19)*	Manufacturing
5	**Electricity and Gas (ELG)**	*D*	Electricity, gas, steam and air conditioning supply
6	**Construction**	*F*	Construction
		L	Real estate activities
7	**Services**	*G*	Wholesale and retail trade
		H	Transportation and storage
		I	Accommodation and food service activities
		J	Information and communication
		M	Professional, scientific and technical activities
		N	Administrative and support service activities
		R	Arts, entertainment and recreation
		S	Other service activities
8	**Finance**	*K*	Financial and insurance
9	**Public**	*E*	Water supply
		O	Public administration and defence
		P	Education
		Q	Human health and social work activities
10	**Other**	*T*	Activities of households as employers
-	**Not included**	*U*	Activities of extraterritorial organizations and bodies

Definition and aggregation criteria of the ten productive sectors in EUROGREEN model, in accordance with the NACE classification. Column two shows the name of the macro-sectors used in the EUROGREEN model.

Table 3: Households' output, in France (2014), in million Euro

NACE Rev.2	*Indicator*	*Households including sole proprietorship (S14)*	*Non-financial sole proprietorship (S14ANF)*
All branches	Output (P1)	436,376	187,974
	Market output (P11)	237,859	187,508
	Output for own final use (P12)	198,517	466
L68A	Imputed rent output (P12)	168,078	0

ment expenditure in industry i , $Z_{i,j}$[10] is the domestic inter-industry trade (i.e., exchanges of intermediate goods from i to any other industries, including the intra-trade), G_i is the domestic public expenditure, and χ_i is the overall export from industry i (including both intermediate and final goods). Note that the Input-Output approach allows one to recover the total output by simply knowing the vector of total final industry demands (f)[11] and the Leontief inverse to obtain the vector of total output by industry (y). The matrix of Leontief derives from the matrix of technical coefficients (A) which, for each seller i and buyer j, indicates the amount of intermediate goods ($Z_{i,j}$) used by the latter from the former.

$$a_{i,j} = \frac{Z_{i,j}}{X_i}, \quad \forall \quad a_{i,j} \epsilon A \tag{3}$$

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}, \tag{4}$$

$$\mathbf{y} = \mathbf{L} \cdot \mathbf{f} \tag{5}$$

where I is the identity matrix. This structure allows us to focus on the demand-side to describe the dynamic of f (via wages, profits, and so on) and then to obtain the supply side through L. Moreover, as described in section 1.13, we model the innovation process so that it will have a direct effects on the technical coefficients (A) of the two energy industries (Fossil and Electricity).

1.4 International Trade

International trade is based on relatively simple relations. As stated above, the imports are a constant share of output for industries and of final consumption for households. This constancy reflects actual import patterns of the french economy (see Fig. 1). Exports, on the other hand, are negatively affected by an increase in domestic industry prices and they are also driven by an exogenous variation.[12] Thus, productivity gains, via unit labour and intermediate cost (and price) reduction, have positive effects on the current account of trade balance. On the contrary, price inflation should reduce the industry's exports. Thus, exports (χ_t^s) of industry i are given by the following equation: the model thus assumes that current exports (χ_t^s):

$$\chi_{i,t} = (1 + g_\chi)\chi_{i,t-1} \cdot (1 - \gamma_\chi \dot{p_{i,t}}), \tag{6}$$

where $g_\chi = 0.01$ is the exogenous exports growth rate, $\gamma_\chi = 0.8$ is a constant elasticity of exports to domestic price variations, and $\dot{p_{i,t}}$ is the variation of industry's i prices in t with respect to the previous period.

We acknowledge the complexity of the international trade issue and the difficulty to accurately replicated one of its most important variables: exchange rates. It is difficult even to select a theoretical basis for exchange rate determination since the most likely candidates such as Purchase Power Parity (PPP) and Uncovered Interest Parity (UIP) have been shown to be empirically flawed ((8, 9)). Moreover, any reasonable attempt would require modelling prices and demand of the trading partners as well as international capital flows and currency carry trade activity which seems to be an

[10] In the equation above we represent the same variable as $Z_{i,j}$ to indicate where the sum applies.

[11] In accordance with national accounting, total final uses include final consumption expenditure of households, non-profit institutions serving households (NPISH), and the public sector, plus gross fixed capital investment, changes in inventories, and exports. Although changes in inventories are not modelled, they are considered in the calculation of technical coefficients. For the calculation of technical coefficients, the output of the Construction and real estate sector is reduced by the amount of imputed rents, which show up as final consumption of households. The corresponding amount is also subtracted from the value added of the sector.

[12] About 1% per year with the sole exception of the simulations that include consumption de-growth. That is to avoid an increase in exports due to falling prices that would, ultimately, offset the contraction of domestic demand and greenhouse gas emissions from consumption de-growth.

important determinant of contemporary exchange rate movements ((18)).

Therefore, our approach to limits itself to model price effects on exports that reflect relative (to foreign competitors, ceteris paribus) increases in competitivity of national industries while considering income as the sole determinant of imports.

1.5 Households' Income, Taxes, and Consumption

Macroeconomic models in the tradition of Michal Kalecki (1971; 2009 [1954]) pay attention to the effect of *income distribution* on the aggregate demand for final goods and services in the economy. The basic assumption is that workers consume a larger share of their income than capitalists (i.e., workers save less), so that a more progressive distribution of income raises the aggregate demand. All households in each group are assumed equal, to say we model the behaviour of a representative household within each skill stratum. The consumption mix is determined by consumer preferences, which are fixed, as shown in Fig. 1.

Variables referring to wage-earners, meaning individuals in the working-age range 15-64 except capitalists, carry the subscript $j = \{L, M, H\}$ to denote skill level (low, medium, and high, respectively), and the subscript $m = \{E, U\}$ to denote employment status (employed and unemployed, respectively). The number of employed workers in each skill category ($L_{j,m}$) is the sum of their employment in each industry (i). Hence, the number of employed workers is given by:[13]

$$L_{j,E} = \sum_i L_{j,i,m} \tag{7}$$

while the unemployed ones are represented by:

$$L_{j,U} = N_j - L_{j,E} \tag{8}$$

where N_j is the total number of households in the j-th skill category. Hence, the total amount of employed and unemployed are $L_E = \sum_j L_{j,E}$ and $L_U = \sum_j L_{j,U}$, respectively. Moreover, we represent the inactive, out of the labour force, population as N_I, the number of working-age adults (age 18-64) as N_A, the number of children (age 0-17) as N_F and the number of individuals aged 65 or above as N_P, who are all assumed to be pensioners (see Table 9 for the actual distribution). Finally, N_C is the number of capitalists, representing a fixed share of 0.1% of the adult population (age 18 and above).

Let households have two sources of funds to finance their consumption; the flow of *income* over the period and the *stock of wealth* which is based on the portfolio choice model (in the following subsection). Savings are the difference between total income and total consumption and they are added to the stock of wealth at the end of the period.

We assume that all wage-earning households have higher propensities to consume than capitalist households (kp).Households decide how much to consume over the year in relation to their expected (rather than actual income) for that year. We assume that households expect their income to be equal to their realized income of the previous year. Incorrect expectations do not affect current consumption, showing up instead as unforeseen changes in deposit holdings.[14] The propensities to consume out-of-income (α_j^y) and out-of-wealth (α_j^v). We assume that they are constant with

[13]The conventional assumption that all work is full-time, means that the model is not able to address powerful *feminist* arguments for Working Time Reduction (WTR). Real-world households are often composed of a male full-time worker and a relatively underpaid female part-time worker. WTR would allow a more equal distribution of unpaid domestic work and – perhaps combined with a legislated right to full-time employment – could gain more economic independence for women. Moreover, the scope for WTR, in the face of a growing dependency ratio, is arguably improved by the prospect that WTR allows many part-time workers to move on to full-time employment.

[14]This Modigliani consumption function implies that households aim to achieve a certain target ratio between their stock of wealth and their flow of income (13, p. 77).

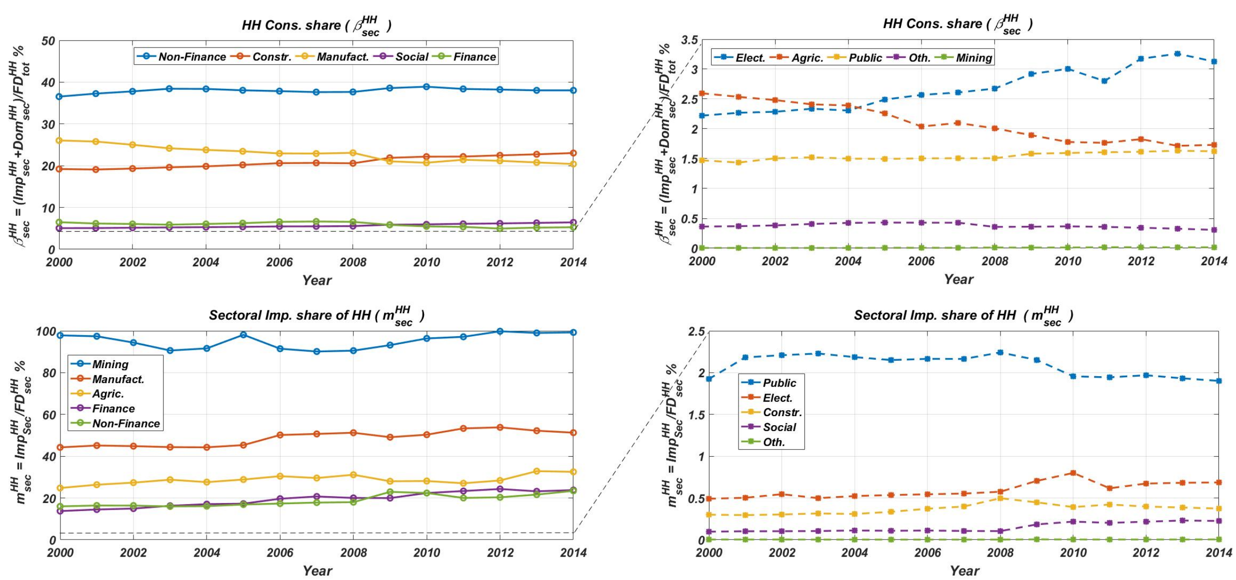
the following relations:

$$\alpha_j^y = 0.9 > \alpha_j^d; \qquad \alpha_{kp}^d = 0.8;$$
$$\alpha_L^d = 0.2, \quad \alpha_M^d = 0.8, \quad \alpha_H^d = 0.7$$

where the subscript kp stands for the capitalist's category of consumers, and L, M, H stand for the three sill categories. Hence, all workers have a higher propensity to consume out-of-income than capitalists, while out-of-wealth the conditions differ.

Some stylized facts on consumer behaviour for France are presented below. Top panels of Fig. 1 shows the share of households' consumption by industry ($\beta_i = \frac{f_i}{\sum_i f_i}$), which are rather stable over the whole time window.

Figure 1: *Time series of the share of import (m) and sectoral (β) consumption for each sector, for households, from 2000 to 2014, in France. Source: WIOD 2016 (own calculations).*



The bottom panels of Fig. 1 shows the share of imports in the households' consumption expenditure for each industry ($m_i = f_i^{imp}/(f_i + f_i^{imp})$). It emerges that imports are significant only in case of agriculture (∼6.60%) and manufacturing (∼13.60%), while in the other industries demand is almost completely domestic.

Table 4 reports data for the 2014 and the average rate of growth in the period 2000-2014. There is a slight reduction on manufacturing expenditure (-0.38%) and a slight increase in construction (0.26%). In the other industries, changes are negligible. Hence, we assume that households' share on consumption are constant over time. Note that, for the sake of simplicity, we omit the households' expenditure in mining and public sector because the share is close to zero.

For a detailed description of public sector expenditure see Section 1.17.

1.6 Employed workers

We assume that the average annual working hours are exogenous, although they differ across industries (h_i). The first component of the **employed** workers' income is the sum of their gross wage bill from each industry ($GWB_{i,j}$), that is given by the hourly wage ($w_{j,i}$) multiplied by the average annual hours and the number of employed workers in a

Table 4: Average import (m) and sectoral (β) share expenditure for households and government (Gov), from 2000 to 2014, in France. Source: WIOD 2016 (own estimations).

Sector	m^{HH}	β^{HH}	m^{Gov}	β^{Gov}
Agric.	28.80 %	2.10 %	46.40 %	0.00 %
Mining	95.12 %	0.01 %	100.00 %	0.00 %
Manufact.	48.69 %	22.85 %	85.78 %	3.24 %
Constr.	0.37 %	20.91 %	48.63 %	2.78 %
Non-Finance	18.79 %	37.98 %	44.55 %	9.47 %
Finance	19.42 %	5.92 %	100.00 %	0.00 %
Elect.	0.60 %	2.67 %	100.00 %	0.00 %
Public	2.09 %	1.54 %	14.66 %	37.96 %
Social	0.15 %	5.64 %	0.08 %	46.48 %
Oth.	0.00 %	0.38 %	0.01 %	0.06 %

certain skill j.[15]

$$GWB_j = \sum_i w_{j,i} h_i \cdot L_{i,j} \tag{9}$$

$$GWB = \sum_j GWB_j. \tag{10}$$

The wage tax has two components, a flat tax (t^A) and a progressive one (t^B). The type A tax combines the *contribution sociale généralisée* (CSG) and the *contribution au remboursement de la dette sociale* (CRDS) into a single 9.7% flat tax (specific to employees) levied on 98.25% (tax base factor independent of employment status) of gross pay, hence $t^{A,E} = 0.097 \cdot 0.9825 = 0.0953$.[16] Thus, the type A for employess in skill j is $T^A_{i,j} = t_A \cdot \sum_i w_{j,i} h_i L_{i,j}$. Type B tax is a progressive tax, varying according to the schedule in Table 5, for which the overall income is split into five brackets (in the range $[\underline{b}_f, \overline{b}_f[$ for $f = \{1, ..., 5\}$). The type B taxable income is smaller than the type A base. Tax-free allowances are made for 6.8 percentage points of the CSG, compulsory social security contributions, and work-related expenses (17).

Compulsory social security contributions by employees (national accounts indicator D613) are approximated to 14% of gross wages (compare (17, p. 260-265). Work-related expenses are calculated using the standard allowance of 10% of gross earnings ((17, p. 262)). Hence, the type B taxable hourly income per employee is $w^B_{i,j} = 0.692 \cdot w_{i,j} = (1 - 0.068 - 0.14 - 0.1) w_{i,j}$. Hence, type B tax per employee is:

$$t^B_{i,j} = \sum_f^4 t^B_f \cdot min[(\overline{b}_f - \underline{b}_f), max((w^B_{i,j} - \underline{b}_f), 0)] + t^B_5 \cdot max[(w^B_{i,j} - \underline{b}_5), 0] \tag{11}$$

For each bracket, the equation first checks whether the taxable income is higher than the floor of the bracket. After that, the equation checks whether the taxable income is higher than the bracket ceiling. Total type B taxes of skill-group

[15] See subsection 1.12 for the definition of wages in the model.

[16] For the CSG, the 9.2% rate of 2018 is used instead of the 7.5% rate of 2014 (Service-public.fr, 2018).

Table 5: Tax schedule for taxable annual income, 2014.
Source: (17, p. 264)

2014	*Fraction of taxable income in €* $(\underline{b}_f \vdash \overline{b}_f)$	*Rate %* (θ^B_f)
Bracket 1	$0 \vdash 9{,}690$	*0*
Bracket 2	$9{,}690 \vdash 26{,}764$	*14*
Bracket 3	$26{,}764 \vdash 71{,}754$	*30*
Bracket 4	$71{,}754 \vdash 151{,}956$	*41*
Bracket 5	$> 151{,}956$	*45*

j employees are then $T^B_j = \sum_i t^B_{i,j} \cdot L_{i,j}$. The net wage bill by skill (NWB_j) is:

$$NWB_j = GWB_j - T^A_j - T^B_j - D613_j \tag{12}$$

where $D613_j = 0.14 \cdot GWB_j$ is the aggregate social contributions of skill-group j employees. In the baseline scenario, type B tax bracket floors change in 1:1 proportion to the economy-wide average yearly wage ($\overline{w_t}h$), so that:

$$\frac{\Delta b_f(t)}{b_f(t-1)} = \frac{\overline{w_t}h}{\overline{w_{t-1}}h} - 1 \qquad for \quad f = \{2,3,4,5\} \tag{13}$$

then $b_{f,t} = b_{f,t-1} + \Delta b_{f,t} = b_{f,t-1}\frac{\overline{w_t}h}{\overline{w_{t-1}}h}$.

1.6.1 Unemployment benefits

The skill-specific nominal gross **unemployment** benefit (GUB_j) is a (constant) fraction (ϖ) of the average skill-specific cross-industry wage, in the previous period. Due to lack of data, we do not have the number of completely unemployed benefit recipients,[17] therefore, we adopt a coverage ratio ($cr_U = 0.8$) of the unemployed population receiving unemployment benefits to obtain the gross unemployment benefits per covered unemployed worker in skill-group j as:

$$GUB_{j,t} = cr_U \cdot (\varpi \frac{GWB_{j,t}}{L_{j,t}}) \tag{14}$$

$$GUB_t = \sum_j GUB_{j,t} \cdot L_{j,t,U} \tag{15}$$

where GUB is the total gross benefits for unemployment and $\varpi = 0.57$ the benefit-to-wage ratio. According to Eurostat's COFOG database, the general government sector incurred € 42,016 million unemployment-related expenditures in 2014, of which € 36,301 million cash benefits (national accounts indicator D62). We assume that all recipients

[17] According to the OECD Social Benefit Recipients Database (SOCR), 2,254,202 persons received Unemployment Insurance (UI) and 434,903 persons received Unemployment Assistance (UA) in 2014, all from public institutions. The database refers to UI as "Jobseeker's benefit" and the UA as "Specific solidarity benefit". The UI program name is "ARE (Aide au retour à l'emploi)", and the UA programme name is "ASS (Aide Spé cifique de solidarité)" (SOCR_Metadata_FRA.pdf). There may be an overlap between programs, and many recipients are partially employed. See OECD SOCR files SOCR_UBPseudoCoverageRates.xlsx; BenRecipients_FRA_2016.xlsx.

of unemployment benefits are completely unemployed.[18] The ratio of unemployment benefits to wages is based on the OECD Tax-Benefit Model. [19] Accordingly, for wages representing between 70% and 200% of the average wage (AW), the benefit-wage ratio is constant at 57%.[20]

The type A tax is charged at 6.7% on 98.25% of gross unemployment benefits (Service-public.fr, 2018), hence $t^{A,U} = 0.067 \cdot 0.9825 = 0.0658$. Total type A taxes of unemployed workers in skill-group j are then $T_j^{A,U} = t_{A,U} \cdot GUB_j$. In type B taxes, allowances are made for 3.8% of CSG,[21] and for social contributions. Based on the OECD Tax-Benefit Model, unemployed persons are assumed to pay 5.3% of gross unemployment benefits in social contributions.[22] Hence, the type B taxable unemployment benefit per person is $GUB^B_{j,U} = 0.909 \cdot GUB_j = (1 - 0.038 - 0.053)GUB_j$. Type B tax per covered unemployed person is determined as for employees (but without the need to sum over industries) as:

$$t_j^{B,U} = \sum_f^4 t_f^B \cdot min[(\bar{b}_f - \underline{b}_f), max((GUB_j^B - \underline{b}_f), 0)] + t_5^B \cdot max[(GUB_j^B - \underline{b}_5), 0] \tag{16}$$

then the total type B taxes from unemployed workers in skill-group j are $T_j^{B,U} = cr_U \cdot t_j^{B,U} \cdot L_{j,U}$. The net unemployment benefits (NUB_j) in skill-group j is

$$NUB_{j,t} = GUB_{j,t} - T_{j,t}^{A,U} - T_{j,t}^{B,U} - D613_{j,t}^U \tag{17}$$

where $D613_j^U = 0.053 \cdot GUB_j$ is the aggregate social contributions of skill-group j unemployed.

1.6.2 Retirees

The third group of individuals are the **pensioners**, that are assumed to be given by the population above 65 years old (N_P). Their income depends on a public pension and individual benefits are proportional to average annual income of each skill category. Let pw be the pension-to-wage ratio,[23] assumed to be a fixed parameter, calculate as:

$$pw = \frac{D62^{OS}}{\sum_j \overline{w_j} h \cdot N_{j,P}} = 0.799 \tag{18}$$

where $\overline{w_j}h$ is the skill-specific average annual gross wage (including self-employed workers assumed to earn the same hourly wage as employees), $N_{j,P}$ is the population aged 65 or over in stratum j, and $D62^{OS}$ is the cash transfers in the "Old age and Survivors" benefits categories in Eurostat's COFOG database. These transfers are assumed to vary in proportion to the number of individuals aged 65 or above in each stratum.[24] The resulting pension-to-wage ratio (pw)

[18] In reality, "in France, in the second quarter 2015, about 700 thousand beneficiaries of the unemployment insurance were in work" (OECD SOCR Database, http://www.oecd.org/social/recipients.htm).

[19] Available at OECD.Stat under Benefits, Taxes and Wages - Net Incomes, https://stats.oecd.org/Index.aspx?DataSetCode$=$FIXINCLSA.

[20] Below 70% of AW, the ratio increases gradually, eventually reaching 75%.

[21] "CSG et CRDS sur les revenus d'activité et de remplacement" (https://www.service-public.fr/particuliers/vosdroits/F2971).

[22] This percentage (5.26%) is constant from 70% to 200% of AW, and somewhat lower below the 70% level.

[23] In France, the minimum legal pension age is 62 years, and the full rate pension age is 67 years ((6, p. 42) and (16, p. 249)). According to the OECD Pensions at a Glance database, the employment rates of older workers in 2014 were: 68.3% for ages 55-59, 25.1% for ages 60-64, and 5.6% for ages 65-69. The effective labour market exit age was 59.4 years for men and 59.8 years for women. However, due to the lack of data on activity or retirement before and after the (internationally non-standard) age of 62, we proceed as if the retirement age were 65.

[24] In reality, according to (5, p. 326), the total number of pensioners in France in 2013 were 18,390 thousand, of which 6,134 thousand (33.4%) aged below 65 and 12,256 thousand aged 65 or above.

in 2014 was 79.9% (71.0% excluding survivors' benefits). Hence, the gross pension benefit (GPB_j), by skill is:

$$GPB_j = pw \cdot \frac{GWB_j}{L_{j,E}} \cdot N_{P,j} \tag{19}$$

The type A tax is charged at 8.8% on 100% of gross old-age pensions (Service-public.fr, 2018), hence $t^{A,P} = 0.088$. Total type A taxes of the 65+ cohort in stratum j are $T_j^{A,P} = t^{A,P} \cdot GPB_j$.

For type B taxes, allowances are made for 5.9% of CSG, and for social contributions. Pensioners pay 7.3% of gross income in social contributions, so that type B taxable income per pensioner is $GPB_j^B = 0.868 \cdot GPB_j = (1 - 0.073 - 0.059)GPB_j$. Type B tax per covered retired person is determined as for unemployed:

$$t_j^{B,P} = \sum_f^4 t_f^B \cdot min[(\overline{b}_f - \underline{b}_f), max((GPB_j^B - \underline{b}_f), 0)] + t_5^B \cdot max[(GPB_j^B - \underline{b}_5), 0] \tag{20}$$

Thus, the total type B taxes from retirees in skill-group j are $T_j^{B,P} = t_j^{B,P} \cdot N_{j,P}$. The net pensioners benefits (NPB_j) in skill-group j is:

$$NPB_j = GPB_j - T_j^{A,P} - T_j^{B,P} - D613_j^P \tag{21}$$

where $D613_j^P = 0.073 \cdot GPB_j$ is the aggregate social contributions of pensioners in skill-group j.

1.6.3 Other social protection transfers

In addition to old age and survivors' pensions and unemployment benefits, EUROGREEN includes other social protection transfers that are also affected either by the basic income (BI) or job guarantee (JG) policy. Table 6 presents a non-comprehensive breakdown of social protection expenditure of S13, focusing on D62 and D632.

Social transfers in kind are excluded from the analysis due to the assumption, following (4, p. 4), that public services or other in-kind support are not directly affected by the BI reform. The modelling of social protection expenditures concentrates in cash transfers, ignoring in-kind provision of goods and services, which instead are aggregated into the final consumption expenditure of general government, as in the national accounts.

Aggregate cash transfers (D62) for social protection (SP) purposes (in million €) are given by: $D62^{SP} = \sum_{j \in \{H,L,M\}} D62_j^{SP}$, which, for each socio-economic stratum, breaks down into:

$$D62_j^{SP} = D62_j^{SD} + D62_j^{OS} + D62_j^{FC} + D62_j^{U} + D62_j^{RSA} \tag{22}$$

where SD is Sickness and disability, OS is Old age and Survivors, FC is Family and children, U is Unemployment, and RSA is Social exclusion n.e.c (only received by low-skill households). Given the relatively small size of cash benefits in the categories Housing and Social protection they are omitted from the model. For simplicity, we assume that all other social transfers are non-taxable and that no social contributions are levied on them. Following (4, p. 4), the BI reform leaves existing social contributions untouched, but none are levied on the BI.

The € 34,608 million spent on **Sickness and disability** under D62 in 2014 (see Table 6) are assumed to be paid in equal amounts to all working-age adults (18-64), independent of skill level, as the number of actual recipients is not modelled. For a cohort of 39,439,670, this gives an annual benefit per capital of € 877.48. Following (1, p. 5), we assume that disability benefits are reduced by the amount of the BI for actual recipients. To estimate this reduction, we use the residual of the savings on non-pension benefits for a BI set at the guaranteed minimum income (GMI) level (€ 465 per month in 2015, net of taxes, see (1, p. 12), obtained after subtracting D62 transfers for Unemployment and Social exclusion n.e.c. (which the BI replaces in full) from total savings on non-pension benefits calculated for France in 2015 by (1, p. 11): *Reduction of disability benefits* = 69,400 - 36,301 - 16,070 = 17,029 million €.

(4, 1) include a BI for each under-age person, set at 100 euros per month in 2015 to equal contemporary **family**

Table 6: General government expenditure on social protection, 2014 (million euros).
Source: Eurostat COFOG.

Code	**COFOG99**	*Total*	of which D62	of which D632
GF10	Social protection	*526731*	419965	34393
GF1001	Sickness and disability	*59067*	34608	3464
GF1002	Old age	*291652*	266602	5926
GF1003	Survivors	*34054*	33645	0
GF1004	Family and children	*53850*	31217	6845
GF1005	Unemployment	*42016*	36301	0
GF1006	Housing	20090	*1099*	16738
GF1007	Social exclusion n.e.c.	*21619*	16070	1420
GF1008	R&D Social protection	*0*	0	0
GF1009	Social protection n.e.c.	*4382*	422	0

Total = Total general government expenditure;
D62 = Social benefits other than social transfers in kind;
D632 = Social transfers in kind - purchased market production;
n. e. c. = not elsewhere classified.

and children benefit payments: "For children, the BI amount is set such that a two-adult two-child family receiving GMI benefits and without any other source of income continues to receive the same amount of support as under the existing tax-benefit system. (...) So in mathematical terms, twice the adult BI amount is subtracted from the amount of GMI benefits received by a two-adult two-child family, and then the result is divided by two." ((1, p. 5)). According to Eurostat data for 1 January 2015, the population aged 0-17 year was 14,782,542. The corresponding annual cost of the BI for children is € 17,739 million. This leaves 31,217 - 17,739 = € 13,478 million. The remaining amount is mainly child-related (Eurostat, 2016: 36). Therefore, as EUROGREEN is not a micro-model with different household types, it makes no difference to separate out the BI for children from the rest of family and children expenditures. We divide total cash benefits (D62) in this category by the number of children in 2014, yearly a quarterly benefit of € 2,111.6 per under-age person in 2014Q4. Benefits of stratum j are given by: $FC_{j,t} = FC^{PC}_{j,t} \cdot \overline{g}_{CPI,t} \cdot N_{j,F}(t)$, where $FC^{PC}_{j,t}$ is the amount per child, and $N_{j,F}$ is the number of children in stratum j. The associated government expenditures are then $D62^{FC} = \sum_j FC_j$.

According to metadata to Eurostat's COFOG database, the category **Social exclusion n.e.c.** mainly includes the *revenu de solidarité active* (RSA) social assistance program. In December 2014, 2,886,270 adults received some form of RSA (CAF, 2015). Although part of the RSA program is in-work income support, we assume that RSA is only paid to the unemployed or inactive. Dividing total cash transfers (D62) in this category by the number of RSA recipients gives an average monthly payment of € 464 per recipient, close to the various RSA modalities reported by CAF, as well as the GMI of € 465 in 2015 considered by (1, p. 12).

The yearly amount is € 5568. We make the preliminary assumption that the RSA is paid out to a fixed percentage $cr_{RSA} = 0.451$ of unemployed and inactive low-skilled working-age persons (15-64), calculated as the ratio of RSA recipients to said population in 2014. The BI abolishes the RSA. The JG, if implemented without the BI, abolishes the RSA for the unemployed, but not for the inactive.

1.7 Capitalists

Finally, **capitalists** (kp) receive a gross disposable income (GDI) from ownership of equity and bonds (i.e., financial activities and profits) and a share of the mixed-income derived from NIOT.[25] In total they obtain:

$$GDI_{kp} = GFI + \varphi_{kp} \cdot R_{mix} \tag{23}$$

where GFI is the gross financial income (see subsection 1.10) and R_{mix} is the mixed-income. Since we have no data on mixed-income distribution, we allocate this amount between the three skill of workers and capitalist by their share of national wealth. In case of capitalist the share (φ_{kp}) was around 16.1% in 2014 and kept constant over all the simulation period.[26]

We summarize the main income sources of households by skill and occupational status described above in table 7.

Table 7: List of the income source for workers and capitalists. Working class is divided by skill (high, middle, and low). *RSA* is the *Revenu de Solidarité Active*, *SDB* are the Sickness and Disability benefits, while *FCB* are the Family and Children benefits.

Category	Employed	Unemployed	Inactive	Retired
Low skill	Wages	Unempl. benefits	*FCB*	Pensions
		RSA	*RSA*	
			SDB	
	Mixed Income			
Middle skill	Wages	Unempl. benefits	*FCB*	Pensions
			SDB	
	Financial Income: Public Bonds			
	Mixed Income			
High skill	Wages	Unempl. benefits	*FCB*	Pensions
			SDB	
	Financial Income: Public Bonds, Equity, Dividends			
	Mixed Income			
Capitalists	Financial Income: Public Bonds, Equity, Dividends			
	Mixed Income			

[25] Around 120 milion euro in France in 2014 (see https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE13).

[26] Mixed income also composes part of low, middle and high-skill households income. Just as for capitalists they earn a share of mixed income that corresponds to their total initial financial asset holdings, which is equal to 2.2%, 11.3% and 70.4% for low, middle and high-income households, respectively.

1.8 Wealth, Portfolio Choice, and Finance

1.9 Individual wealth distribution

The distribution of wealth between socio-economic strata is based on data for France from the World Wealth and Income Database (WID.world). This database considers the resident population aged 20 years or over, organized in percentiles.[27] The skill shares of the 20+ population reported in Table 1 can be expressed cumulatively, so that the low-skilled group represents the lower 0-30.7% interval, the medium-skilled the 30.7-71.6% interval, and the high-skilled the 71.6-100% interval. This corresponds quite well to the decile structure of the WID data (with finer divisions at the top). Thus, we map the low-skilled stratum onto the bottom 0-30 percentile, the medium-skilled onto the 30-70 percentile, and the high-skilled onto the 70-99.9 percentile. We reserve the 99.9-100 percentile for the fourth socio-economic category of capitalists, who are assumed not to earn any wages nor wage-based pensions. Representing 0.1% of the 20+ population, the number of pure capitalists is 65,940 (end-2014). The assumption that the difference in educational attainment of the population coincides with the difference in wealth (and income) is, of course, merely an approximation to reality. An additional assumption is implied by the nature of the WID data. The unit of reference is the individual, not the household.[28]

We model portfolio choice following (13), who developed the approach first presented by (3, 19) . This sub-model determines how the composition of the wealth of each socio-economic group responds to variations in the rates of return on different asset classes. We focus on financial wealth, which represented 43.9% of household net wealth in 2014. The remaining 56.1% was mainly housing, but also business assets of the non-financial kind.[29] The WID database considers four classes of financial assets: deposits, bonds, equities, and life insurance and pension funds (LIPF). However, we exclude LIPF from the portfolio choice model, because the historical evolution of its portfolio weight appears based more on political-institutional developments than on relative returns. Instead, the share of financial wealth-held in this form is fixed at its 2014 end-of-year value. This simplification finds some support in the levelling out of this share in recent times.

We assume that the low-skilled stratum holds all of its financial assets as deposits. Therefore, we estimate no portfolio choice equation for this stratum. For the initial values of simulations, we swap the bonds and equities of the low-skilled for deposits of the medium-skilled, so that the former hold only deposits while total quantities are preserved. No portfolio choice equation is estimated for the medium-skilled either. Instead, the composition of their portfolios is fixed at its 2014 value (69% deposits and 31% bonds). The Table 8 represents an empirical justification. The distribution of financial assets (excluding LIPF) across the four socioeconomic groups is shown in Table 3.1. For example, the bottom row shows that the top 0.1% of the adult population holds 16.1% of the financial assets, of which 0.4% of the deposits, 21.4% of the bonds, and 42.3% of the equities.

[27] (11) state that the minimum age considered is 20. However, the figure given for the total resident adult population in 2014 (51,721,509) is closer to Eurostat's figure for the resident 18+ population (51,673,737) than the 20+ population (50,087,875) as of 1 January 2015. The Eurostat figures include all five overseas departments, but possibly not the collectivities nor territories (`http://ec.europa.eu/eurostat/cache/metadata/en/demo$_$pop$_$esms.htm`).

[28] It is usually not possible to divide the wealth of married couples on the basis of unequal individual property rights, in which case the wealth is simply divided by two (Garbinti et al., 2017: 17). The implied assumption in EUROGREEN is that married couples belong to the same skill category. Average adult net wealth in France in 2014 was 197,379 euros (Garbinti et al. 2017: Table B1). This represents financial wealth plus non-financial wealth including housing net of debt. Multiplied by the total adult population figure (51,721,509) in Garbinti et al. (2017: Table B1), the total wealth of adults in 2014 was 10,208,739,724,911 euros, or 10.2 trillion euros.

[29] The wealth composition figures reported in WID satisfy the formula Non-Financial Assets + Financial Assets - Debt = 100%. Using figures of 2014: 69.2% + 43.9% - 13.1% = 100%. Debt is subtracted from housing assets to obtain net wealth.

Table 8: Distribution of financial assets across socio-economic groups, 2014 (%). Source: Own calculations based on (11)).

2014	*Financial assets*	*Deposits*	*Bonds*	*Equities*
Low-skilled	2.2	9.0	0.0 (0.028)	0.0 (0.0074)
Medium-skilled	11.3	31.8	4.3	0.9
High-skilled	70.4	58.7	74.3	56.8
Capitalists	16.1	0.4	21.4	42.3
TOTAL	100	100	100	100

1.10 Financial Income

The pre-tax financial income of the higher three strata (M, H and kp), is the sum of the revenues from each asset class (deposits, bonds and equities), plus nominal capital gains on bonds and equities. Gross financial income (GFI_j) of stratum j is given by:

$$GFI_{j,t} = \iota_t^D \cdot D_{t-1}^j + \iota_T^B \cdot B_{t-1}^j \sum_i Div_{j,i,t} + G_{j,t-1}^b + G_{j,t}^{Eq,s} \tag{24}$$

where ι_t^D is the current nominal rate of interest on deposits, D is the stock of deposits at the end of the previous period, ι_t^B is the nominal interest rate on government bonds (the long-term interest rate), B is the stock of bonds, and $Div_{j,i,t}$ are the dividend payments by each industry. G^B and are $G^{Eq,s}$ the nominal capital gains on bonds and equities, receptively, calculated as the current change in the price of bonds, times the stock at the end of the previous period:

$$G_{j,t}^b = \Delta p_B \cdot B_j, t-1 \tag{25}$$

$$G_{j,t}^{Eq,s} = \Delta p_E \cdot Eq_{j,t-1}. \tag{26}$$

EUROGREEN adopts a 30% flat tax ($t^F = 0.30$) on financial income (capital gains, dividends and interests) introduced in 2018 (Financial Times, 2017). More precisely, the levy consists of a 12.8% income tax and a 17.2% charge for social contributions (including CSG), but we model it as a single tax. Taxes on financial income paid by stratum j are:

$$T_{j,t}^F = t^F \cdot [\iota_t^D \cdot D_{t-1}^j + \iota_T^B \cdot B_{t-1}^j + \hat{F}_{j,t}^s + max(G_{j,t-1}^b, 0) + max(G_{j,t}^{Eq,s}, 0)] \tag{27}$$

where the max functions ensure that negative capital gains do not give rise to negative taxes. Note that the rate of interest on deposits is assumed to be non-negative. Hence, net financial income ($NFI_{j,t}$) is:

$$NFI_{j,t} = GFI_{j,t} - T_{j,t}^F \tag{28}$$

1.11 Portfolio choice model

In the portfolio choice model, following the tradition of (3) and (19), the rates of return on different assets need not be equal. However, various adding-up constraints can be imposed on the coefficients based on theoretical assumptions. We adopt the vertical adding-up constraint, according to which "the vertical sum of the coefficients in the rates of return matrix must be zero", so that "the sum over all assets of responses to a change in any of the rates of return is zero" (13,

p. 144).[30] Furthermore, we omit the effect of the disposable income to wealth ratio on the demand for deposits, which is usually included in portfolio models of this kind. This omission is due to the lack of data on disposable income by wealth percentile. (11) present this data for the 0.1 percentile, but not for the 70-99.9 percentiles.

We use annual data on asset composition by wealth percentile of the adult population from (11) to calculate the portfolio composition of each stratum. The annual values are interpreted as end-of-year values. The rates of return are annual rates from the WID database. The rates of return are net of taxes, and either include or exclude real capital gains, as specified. The annual values are interpreted as annual averages. The series are interpolated with Bessel splines to obtain the annual equivalent rate for each quarter.[31] Then, for bonds and equities, the quarterly rate is obtained by dividing the annual rate by four. For deposits, the cumulative interest formula is used instead. Before going ahead let define the different rates of returns as:

- rrbn^*_{cg}: rate of return on bonds, including capital gains, net of taxes;
- rren^*_{cg}: rate of return on equities, including capital gains, net of taxes;
- rrdn^*_{cg}: rate of return on deposits, including capital gains, net of taxes;
- rrdn^*: rate of return on deposits, excluding capital gains, net of taxes.

The three portfolio equations of each socio-economic group can be written in matrix form as:

$$\begin{pmatrix} \Delta \frac{B}{V} \\ \Delta \frac{Eq}{V} \\ \Delta \frac{D}{V} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \cdot \begin{pmatrix} rrbn^*_{cg} \\ rren^*_{cg} \\ rrdn^* \end{pmatrix} \tag{29}$$

where B is the stock of bonds held, Eq the stock of equities, D the stock of deposits, and V the total financial wealth. On the right-hand side, there is a matrix of coefficients, followed by a vector of rates of return. In principle, the own-rates on the main diagonal of the coefficients matrix should be positive, and the others should be negative. The vertical adding-up constraint means that each column of the coefficients matrix should sum to zero. Only the equations for bonds and equities are estimated, and the share of deposits is treated as a residual. Nevertheless, the deposit share equations implied by the vertical constraints are checked. Recall that only the high-skill and capitalists groups are subject to the portfolio choice equations. We assume that individuals in this groups are able to achieve the desired portfolio composition at the end of the period (13, p. 143). Their portfolio shares are given by:

$$\frac{X_{s,t}}{V_{s,t}} = \frac{X_{s,t-1}}{V_{s,t-1}} + \Delta \frac{X_{s,t}}{V_{s,t}} \qquad \forall \quad X = \{B, Eq, D\}, s = \{H, Kp\} \tag{30}$$

In what follows the estimated values[32] for high-skilled group (H):

$$\begin{pmatrix} \Delta \frac{B_H}{V_H} \\ \Delta \frac{E_H}{V_H} \\ \Delta \frac{D_H}{V_H} \end{pmatrix} = \begin{pmatrix} 0.10 & -0.09 & 0 \\ -0.16 & 0.12 & 0 \\ 0.06 & -0.03 & 0 \end{pmatrix} \cdot \begin{pmatrix} rrbn^*_{cg} \\ rren^*_{cg} \\ rrdn^* \end{pmatrix} \tag{31}$$

[30] However, we do not impose the less essential horizontal and symmetry constraints (13, p. 144-145).

[31] Spline interpolation is performed using SRS1 Cubic Spline for Excel software.

[32] All the procedure and the statistical analysis behind these estimations are available on request.

and capitalists (kp)

$$\begin{pmatrix} \Delta \frac{B_{kp}}{V_{kp}} \\ \Delta \frac{E_{kp}}{V_{kp}} \\ \Delta \frac{D_{kp}}{V_{kp}} \end{pmatrix} = \begin{pmatrix} 0.38 & -0.12 & 0 \\ -0.37 & 0.12 & 0 \\ -0.01 & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} rrbn^*_{cg} \\ rren^*_{cg} \\ rrdn^* \end{pmatrix} \tag{32}$$

The equations imply that capitalists are more sensitive than high-skilled workers to the rate of return on bonds for their choice between bonds and equities, although their sensitivity to the rate of return on equities is rather similar. The residual status of deposits is particularly clear for capitalists, whose (very small) share of deposits is virtually unresponsive to relative rates of return.

1.12 Employment, wages, and working time

Our approach takes the level of employment to be determined by employers, since they hire workers and intermediate inputs to meet their demand. Labour supply and its composition shift as a consequence of labour market characteristics, following unemployment rates, but employees' decisions concerning the trade-off between work and leisure is not considered in the model. Given the existing power relations between employers and employees, this is arguably not a serious omission, but it does mean that the model cannot address voluntary down-shifting behaviour.

Labour Supply The *labour force* (LF) is constituted by the two middle cohorts multiplied by the participation rate (ν), then:

$$LF_t = (Pop_{II,t} + Pop_{III,t})\nu_t \tag{33}$$

γ has an initial value of 0.711 and its variation follows movements in the difference between the overall unemployment rate u_t and its initial value of 10.29% according to the following equations:

$$\nu_t = min(0.711(1 - 3.5(u_{t-1} - 0.1029)), 1) \tag{34}$$

The composition of the labour force between the three skills $j = \{L, M, H\}$ [33] varies in a somewhat similar fashion, except that we adopt transition coefficients ($\tau_{j,j}$) that make transitions from higher to lower skills more likely (frequent), than the other way around. The initial compositions of the labour force by skill (s^0_j) is set to 19.5% of low, 48.08% of middle and 32.42% of high-skill workers. Those transit between skills as a function of the differences in skill-specific unemployment rates ($u_{j,t}$) and the above mentioned transition coefficients. The expression for the share of the labour force allocated in low-skill ($s_{L,t}$), for instance, is given by:

$$s_{L,t} = s^0_L(1 + \tau_{L,M}(u_{M,t-1} - u_{L,t-1})) \quad if \quad u_{M,t-1} > u_{L,t-1} \tag{35}$$

$$s_{L,t} = s^0_L(1 + \tau_{M,L}(u_{M,t-1} - u_{L,t-1})) \quad if \quad u_{M,t-1} < u_{L,t-1} \tag{36}$$

the transition coefficients are decreasing on the likelihood of the transition between two skills. That is, a $\tau_{L,M}$ smaller $\tau_{M,L}$ ensures that for differences in unemployment rates of the same magnitude, but with different signs, more middle-skill workers would be able to transit into low-skill than the other way around. The values for the initial transition coefficients are: $\tau_{L,M}$=0.75, $\tau_{M,L}$=1, $\tau_{M,H}$=0.45 and $\tau_{H,M}$=0.85. They are further assumed to gradually increase during the simulations to reflect a greater mobility of labour reaching the final values of 1.1, 1.35, 1.35 and 1.2, respectively.

[33] These categories correspond to OECD usage in terms of educational attainment (respectively: lower secondary level or less, upper secondary and tertiary).

Table 9: Employment and unemployment by skill. *The level of educational attainment is based on year 2014 (average. Source: Own calculations based on Eurostat LFS (https://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey). Notes: Resident population concept; non-respondents proportionally distributed across all skill categories.*

Year 2014	Low-skilled	Medium-skilled	High-skilled	*Total*
Total pop, 15-64	10,880,767	17,922,695	12,192,037	*40,995,499*
Active population, age 15-64	5,418,622	13,173,181	10,558,304	*29,150,107*
Employment, age 15-64	4,481,201	11,763,650	9,882,573	*26,127,424*
Unemployment, 15-64	937,422	1,409,530	675,731	*3,022,683*
Participation rate, age 15-64	0.498	0.735	0.866	*0.711*
Unemployment rate, age 15-64	0.173	0.107	0.064	*0.104*
Person available to work but not seeking (age 15-74)	311,4	308,9	111	*731,3*
Inactive population, age 15-64	5,462,145	4,749,514	1,633,733	*11,845,392*

Labour Productivity The actual labour productivity by industry (λ_i) is a weighted average of the labour productivity that corresponds to the latest technology adopted and that of the previously adopted one. That is, if industry i adopts technology α with labour productivity λ_α in period t, while in all the previous periods it produced using technology β with labour productivity λ_β, its actual labour productivity in period t will be given by the expression below. The weights for the new and old labour productivities are the amount of the fixed capital that embodies these technologies: gross fixed capital formation ($I_{i,t}$) and the stock of fixed capital after depreciation ($(1-\delta)K_{i,t}$).

$$\lambda_{i,t} = \frac{\lambda_\alpha I_{i,t} + \lambda_\beta (1-\delta_i) K_{i,t}}{I_{i,t} + (1-\delta_i) K_{i,t}} \tag{37}$$

The factors that determine the rate and direction of the innovation processes in labour productivity and energy efficiency are described in detail in chapter 1.13 of this appendix.

Employment The amount of employed workers in each industry by skill ($L_{i,j}$) is a function of its output y_i, which in turn depends on final demand, its labour productivity and the yearly working hours in that industry (h_i). The composition of industry employment between the three skills is represented by parameter ($\sigma_{i,j}$) which is calculated for each industry relying on data from the EU KLEMS project.[34] Moreover, following the contemporary labour economics literature (e.g., (14), (2)), it is assumed that technical progress in labour productivity (g_λ) substitutes middle and complements high and, to a lesser extent, low-skill work through the job polarization coefficient (ψ). The employment in industry i of workers in skill j at period t is then represented by the following equation.

$$L_{i,j,t} = (1 + \psi g_{\lambda,t}) \frac{\sigma_{i,j} y_{i,t}}{\lambda_{i,t} h_i} \tag{38}$$

Hours worked are defined by industry but do not differ by skill. Once again they are based on EU KLEMS data

[34] See http://www.euklems.net/project_site.html.

from which we calculate a vector of the difference in yearly hours worked by industry ($\hat{h}_i$) with respect to the economy average of yearly hours, given by the multiplication of average weekly hours (hw) by 43 weeks.

$$h_i = \hat{h}_i hw.43 \tag{39}$$

The evolution of employment, by skill, simulated in the baseline scenario is presented for selected years in table 10. Note, in particular, how the employment polarization trend due the assumed substitution (complementarity) between technological progress and middle-skill (high and low-skill) work introduced by parameters $\psi g_{\lambda,t}$ affects relative employment.

Table 10: Employment by skill as % of total in selected years.

Skills	2014	2030	2050
Low	17.2%	17.6%	18.4%
Middle	44.9%	43.5%	41.7%
High	37.8%	39.0%	39.9%

The overall (u_t) and skill specific ($u_{j,t}$) unemployment rates are then obtained simply as the ratio between the number of unemployed workers and the supply of labour.

$$u_t = \frac{LF_t - \sum_j \sum_i L_{i,j,t}}{LF_t} \tag{40}$$

$$u_{j,t} = \frac{LF_{j,t} - \sum_i L_{i,j,t}}{LF_{j,t}} \tag{41}$$

Wages The initial wages by skill and industry ($w^0_{i,j}$) are calculated using EU KLEMS data as the ratio between total compensation of workers in a skill j employed in industry i and the product between their respective yearly hours worked and number of employees. Their evolution in the model then depends positively on the growth rates of industry employment[35] ($g^L_{j,i,t}$) and productivity ($g^\lambda_{i,t}$).

$$w_{i,j,t} = w^0_{i,j}(1 + \omega_{\lambda,j} g^\lambda_{i,t} + \omega_{L,j} g^L_{j,i,t}) \tag{42}$$

The sensitivity parameters $\omega_{\lambda,j}$ and $\omega_{L,j}$ are fixed in time by vary between skills. In both cases high-skill wages are more sensitive to variations in employment and productivity with the following values.

$$\omega_{\lambda,j} = [0.7, 0.7, 0.9] \quad j = \{L, M, H\} \tag{43}$$

$$\omega_{N,j} = [0.5, 0.5, 0.7] \quad j = \{L, M, H\} \tag{44}$$

[35]The option to render wages sensitive to the growth of employment instead of unemployment rates was taken to reflect a higher degree of stratification between occupations in the economy. Setting wages as a function of employment makes them responsive to industry specific dynamics and couples the labour cost of an industry to its growth and profits

1.13 Innovation: labour productivity and energy efficiency

Industries' investment decisions are considered *innovative* investments if they modify the technical coefficients through a change in labour productivity (λ) and/or energy efficiency (η). In this case, firms aim at minimizing the costs given a (desired) level of production. This decision is highly dependent on the evolution of relative prices of factors of production. The effects on employment depend on the type of investment: for instance, a significant increase in labour productivity (i.e., automation) might result in higher level of unemployment. In EUROGREEN model innovation is partially endogenous, as explained below. Note that new technologies can be installed only in new equipment, and not in the whole (actual) stock of capital. Hence, the amount of labour and energy demanded depend on the mix of technologies operating simultaneously.

In each period the set of available technologies (Ω), among which industries decide, can include several combinations of labour productivity and energy efficiency, as reported in Table 11. The change in productivity ($\Delta\lambda$) or efficiency ($\Delta\eta$) determines the new levels of λ and η, thus we have $\lambda_t = \lambda_{t-1} + \Delta\lambda$ and $\eta_t = \eta_{t-1} + \Delta\eta$, respectively.

Table 11: All possible combinations of available labour productivity (λ) and energy efficiency (η).

Technology	λ	η
Ω_1	$\lambda_{1,t} = \lambda_{t-1}$	$\eta_{1,t} = \eta_{t-1}$
Ω_2	$\lambda_{2,t} > \lambda_{t-1}$	$\eta_{2,t} < \eta_{t-1}$
Ω_3	$\lambda_{3,t} < \lambda_{t-1}$	$\eta_{3,t} > \eta_{t-1}$
Ω_4	$\lambda_{4,t} > \lambda_{t-1}$	$\eta_{4,t} > \eta_{t-1}$

We assume that the previous-period technology (Ω_1) is always available, while the other three cases are assumed to have positive and independent (uniform) probability distributions (Y). The set of all possible available combinations are then five:

Y_1: only Ω_1 is available, implying that $\Delta\lambda = \Delta\eta = 0$;

Y_2: Ω_1 and Ω_2 are available;

Y_3: Ω_1 and Ω_3 are available;

Y_4: Ω_1, Ω_2 and Ω_3 are available;

Y_5: Ω_1 and Ω_4 are available;

Note that, Ω_4 is always strictly less costly and will be chosen whenever it is available.

There is a growing literature studying the drivers of technological progress. In particular, relative input prices - of energy and labour in our case - are crucial in shifting R&D investment decisions. For instance, if energy is becoming relatively costlier than labour, the probability of Ω_3 should increase with respect to Ω_2. This consideration leads us toward an endogenous definition of the probability of emergence of new technologies (Ω), driven by the input-cost ratio, ζ, defined as:

$$\zeta_{\eta,\lambda} = \frac{C_\eta}{C_\lambda} \tag{45}$$

where C_η and C_λ are the total costs of energy and labour, respectively, which are strictly tied to energy prices and wages. The main intuition is that a larger $\zeta_{\eta,\lambda}$ leads to a higher probability of energy-saving innovations because energy becomes relatively more expensive than labour, so that industries' incentive to reduce energy costs becomes relatively larger. In contrast, when $\zeta_{\eta,\lambda}$ decreases, the probability of Ω_2 should increase. We assume that each technology has a probability of arrival of ($P_z = p(\Omega_z)$) that depends on the rate of growth of the input costs ratio ($\dot{\zeta}_{\eta,\lambda}$).[36] That is:

$P_1 = 1$;

$P_{2,t} = P_{2,t-1} \cdot [1 - \vartheta_2 (1 - I_{\dot{\zeta}_{\eta,\lambda}}) \dot{\zeta}_{\eta,\lambda}]$;

$P_{3,t} = P_{3,t-1} \cdot [1 - \vartheta_3 (1 - I_{\dot{\zeta}_{\eta,\lambda}}) \dot{\zeta}_{\eta,\lambda}]$;

$P_{4,t} = P_4$;

where $I_{\dot{\zeta}_{\eta,\lambda}}$ is an indicator function that assumes a unitary value if $\dot{\zeta}_{\eta,\lambda} > 0$, and zero otherwise, while ϑ_2 and ϑ_3 are positive parameters. Note that $P_1 = 1$ because Ω_1 is always available, and that P_4 is constant because the probability of obtaining win-win innovations - that is, innovations that are both labour and energy efficient - does not depend on the input cost ratio. Thus, assuming that the P_z are independent and identically distributed random variables, we can simply recover the probability of each technological combination as:

$Y_1 = (1 - P_2)(1 - P_3)(1 - P_4)$;

$Y_2 = P_2 (1 - P_3)(1 - P_4)$;

$Y_3 = P_3 (1 - P_2)(1 - P_4)$;

$Y_4 = P_3 P_2 (1 - P_4)$;

$Y_5 = P_4 [(1 - P_2)(1 - P_3) + P_2 (1 - P_3) + P_3 (1 - P_2)]$.

Since new technologies can be incorporated only in new equipment, and not in the entire current stock of capital (k_t), the amount of labour and energy applied depends on the technological mix. Hence, industry compute the average productivity of labour, as shown in equation 37, and energy efficiency, $\eta_{i,t}$, associated with each available technology, given the level of gross fixed capital formation ($I_{i,t}$, see Section 1.14) and stock of capital (k_t)[37]:

$$\eta_{i,t} = \frac{\eta_\alpha I_{i,t} + \eta_\beta (1 - \delta_i) K_{i,t}}{I_{i,t} + (1 - \delta_i) K_{i,t}} \tag{46}$$

These indicators are then applied in the computation of the overall energy and labour costs related to each technology to compute the total costs of each available technology ($C_{\Omega_o,t}$) and select the lowest one. Therefore, the dynamics of relative costs, viz. energy prices and wages, plays a crucial role in the selection among available technologies. The definition of alternative probability distributions (Y) allows us to define several scenarios on the aftermath of public policies on innovative process: for instance, "green" policies should intervene to increase Y_3 which is associated with higher energy efficient coefficients.

1.14 Investments, Prices and Profits

Investment behaviour in the model is conditioned by capacity utilization rates, an exogenous non-capacity creating component and profits that have a dual role. While an increase in profit rates foster further investments, they are limit investments as part of the desired expansion of capital must be financed by profits after debt repayments.

[36] The rate of growth of input cost ratio is, in theory, not constrained. However, in data we do not observe changes greater (lower) than 1 (-1). For this reason, we assumed that $-1 < \dot{\zeta}_{\eta,\lambda} < 1$.

[37] In the following equation, as in equation 37, α and β represent a newly adopted and the formerly prevalent technologies, respectively

Capacity utilization An industry's capacity utilization rate ($uc_{i,t}$) is simply the ratio between real output and its full capacity output ($y_{i,t}^{FC}$).

Therefore, the expression for capacity utilization in industry i at time period t is:

$$uc_{i,t} = \frac{y_{i,t}}{p_{i,t} y_{i,t}^{FC}} \tag{47}$$

Full capacity output varies with the stock of capital and is obtained multiplying it by a fixed capital productivity ($\epsilon_{K,i}$) that is calculated as the initial real output divided by the product between the initial stock of capital and the normal capacity utilization rates (uc_i^N). Therefore, full capacity is here considered as 'practical capacity', defined as "the output achieved with normal length of working time, with sufficient shut-downs to allow for repairs and maintenance, and without disturbance in the smooth running of the production process" (Steindl 1952 cit. in Lavoie 2014: 148) instead of the maximum possible output that might be achieved.

$$y_{i,t}^{FC} = \epsilon_{K,i} K_{i,t} \tag{48}$$

$$\epsilon_{K,i} = \frac{y_i^0}{p_i^0 K_i^0 uc_i^N} \tag{49}$$

Investment function, credit and finance The desired investment in each industry ($\hat{I}_i$) depends on some of the usual variables applied in post-keynesian investment functions. In addition to the capacity utilization, industries have a fixed exogenous component in their investment functions that does no increase productive capacity, that is, does not add to the stock of capital. This term (z) follows some of the recent post-keynesian growth literature ((10, 12)) and represents expenditures that are complementary to capacity creating investments such as research and development, housing, and infrastructure investments.

The after tax profit rate ($\pi_i = \Pi_i / K_i$) also has a positive impact on investments in addition to the rate of capital depreciation (δ_i) which is compensated by investment every period. Hence, the expression for desired investment in industry i is given by[38]:

$$\hat{I_{i,t}} = (\varsigma_{1,i} \pi_{i,t} + \varsigma_{2,i}(uc_{i,t-1} - uc_i^N) + \varphi + \delta_i) K_{i,t-1} \tag{50}$$

This desired investment is, however, limited by an industries capacity to partially finance investments with its own profits. Thus, in the model profits, after debt repayment ($\tilde{\Pi}_i$), must finance a fixed proportion of investment determined by an debt-to-equity ratio ($edr = 0.133$)[39]. Since the desired investment is defined in real terms, maximum investment is corrected by the price of capital ($p_{K,t}$)[40]

Hence, the maximum investment that may be performed in a certain period is represented by:

$$I_{i,t}^{max} = \frac{\tilde{\Pi}_i}{p_{K,t} edr} = \frac{\Pi_i - i_{t-1}.H_{i,t-1}}{p_{K,t} edr} \tag{51}$$

[38]The sensibility parameters in the equation below have the following values: $\varsigma'_{1,i} = [0.01, 0.10, 0.01, 0.10, 0.10, 0.10, 0.10, 0.10, 0, 0]$; $\varsigma'_{2,i} = [0.125, 0.125, 0.125, 0.075, 0.025, 0.050, 0.075, 0.125, 0.050, 0.000]$

[39]In other words, an industry must have free cash flow to finance at least around 15% $\approx 0.133/(1-0.133)$ of total investments while taking the remaining amount in credit.

[40]The price of capital is a weighted average of the prices of three industries: manufacturing, construction and services. Their respective weights are 0.1624, 0.4616 and 0.376 which approximately correspond to the amount of goods and services demand for gross capital formation in the whole economy, based on the 2014 French input-output table in WIOD. The remaining industries supply a small part of goods and services that compose investments and are, therefore, set to zero.

Where H_i are the stocks of private debt and i their respective interest rate. The initial stock of debt is set as a fixed proportion of an industry's capital stock that represents their desired leverage ratio ($lev = 0.4$). Debt then changes in time as a function of nominal investments.

$$H_{i,t} = H_{i,t-1} + I_{i,t}^{nom} - \tilde{\Pi}_i \tag{52}$$

$$H_i^0 = lev\dot{K}_i^0 \tag{53}$$

Note that in this set-up the limits imposed by profit availability also have a dynamic effect on investments. An increase in investment in period t also raises private debt and, consequently, the amount of future profits that will be allocated to repay it, thus leaving less free cash-flow to finance investments in $t+1$.

Gross fixed capital formation and capital accumulation The actual gross fixed capital formation is then the minimum between desired and maximum possible investment that can be financed:

$$I_{i,t} = min(\hat{I_{i,t}}, I_{i,t}^{max}) \tag{54}$$

And in nominal terms:

$$I_{i,t}^{nom} = p_{K,t} I_{i,t} \tag{55}$$

The evolution of capital stock thus increases with investment, except for the non-capacity creating component and is reduced by depreciation as:

$$K_{i,t} = K_{i,t-1} + I_{i,t} - (\varphi + \delta_i) K_{i,t-1} \tag{56}$$

Price Setting In the EUROGREEN model industries follow set a mark-up over their unit cost to determine prices. On the cost-side, they consider the full cost of labour (ulc), including taxes, and of intermediate inputs (uic), including imports, per unit of output while transferring to prices the cost increase imposed by VAT taxes (t_i^{VAT}). To that they add a fixed mark-up ($\bar{\mu}$) which is incremented by gains in labour productivity (g_λ) and eventual accelerations of capacity utilization.

The expressions below describe the unit cost of labour and intermediate goods, respectively. Unit labour cost is equal to the gross wage bill of an industry i incremented by employers' social contribution (t_i^{lab})[41] and divided by industry output. Unit intermediate cost, on the other hand, is the sum of the intermediate goods industry i acquires from the other industries ($\sum_i Z_{i,i}$), from other industries abroad ($\sum_i Z_{i,i}^{imp}$) and capital depreciation in proportion to its output.

$$ulc_{i,t} = \frac{\sum_j GWB_{i,j,t-1}(1 + t_i^{lab})}{y_{i,t-1}} \tag{57}$$

$$uic_{i,t} = \frac{\sum_i Z_{i,i,t-1} + \sum_i Z_{i,i,t-1}^{imp} + \delta_i K_{i,t-1}}{y_{i,t-1}} \tag{58}$$

Let us define the whole mark-up over unit cost ($\mu_{i,t}$) as the sum of a fixed initial markup ($\bar{\mu}$)[42] that varies withe the

---

[41] The tax rate of social contributions in the ten industries is equal to $\sum_i z'_{i,i,t-1} = [0.4313, 0.3991, 0.6987, 0.372, 0.8171, 0.2596, 0.3186, 0.4355, 0.5065, 0.1706]$.

[42] The values for the fixed mark-up component are $\mu'_{i,t} = [0.003, -0.0138, 0.0763, 0.0431, 0.1237, 0.104, 0.0557, 0, 0, 0]$.

growth of labour productivity (g_λ)[43] plus the VAT tax rate and the variation of capacity utilization with respect to its normal value. However, we assume that prices are rigid downward with respect to capacity, that is, industries do not reduce prices if capacity utilization is below its normal level.

$$\mu_{i,t} = \bar{\mu}(1 + \kappa_1 g_{\lambda,i,t-1}) + max(uc_{i,t-1} - uc_i^N, 0) + t_i^{VAT} \tag{59}$$

Finally, putting together the last three equations we may define prices as a mark-up over unit cost.

$$p_{i,t} = (1 + \mu_{i,t})(ulc_{i,t} + uic_{i,t}) \tag{60}$$

Profits Gross profits ($\hat{\Pi}_i$) are determined as value added (VA_i) minus labour costs and value added taxes. We start presenting the expression for industry value added which is the total value of its outputs net of intermediate costs.

$$VA_{i,t} = y_{i,t} - \sum_i Z_{i,i,t} + \sum_i Z_{i,i,t}^{imp} \tag{61}$$

Then, as mentioned abode, the gross wage bill incremented by employers social contributions is subtracted to obtain gross profits.

$$\widehat{\Pi_{i,t}} = VA_{i,t}(1 - t_i^{VAT}) - \sum_j GWB_{i,j,t}(1 + t_i^{lab}) \tag{62}$$

Finally, gross profits minus corporate income taxes give the expressions for net profits. The model adopts the actual schedule of the french government to reduce corporate income taxes from its initial rate of 33% in 2014 to 25% by 2022[44].

$$\Pi_{i,t} = \widehat{\Pi_{i,t}} - max(t_i^{CIT}\widehat{\Pi_{i,t}}, 0) \tag{63}$$

Part of net profits is distributed among households, according to their equity holdings. Dividends are a fixed proportion of net profits ($\varrho = 0.3$) whenever they are positive.

$$Div_{i,t} = \varrho.max(\Pi_{i,t}, 0) \tag{64}$$

[43] Industries adjust prices differently as a consequence of labour productivity growth with the following values: $\kappa_1' = [10, 10, 50, 50, 50, 50, 30, 30, 0, 0]$

[44] The schedule predicts an initial reduction to 31% in 2019, followed by further tax cuts to 28%, 26.5% and finally 25% in 2020, 2010 and 2022, respectively.

1.15 Energy, Greenhouse Gas Emissions, and Carbon Taxes

Energy demand is split between four sources: gas, oil, coal and electricity. Electricity, in turn, is produced with different sources: nuclear, renewable, gas, coal, and oil. Table 12 shows the fuel shares for Total Primary Energy Supply (TPES) and Electricity for France in 2016.

Table 12: Fuel shares for Total Primary Energy Supply (TPES) and Electricity, 2014. Source: IEA (https://www.iea.org/statistics).

Fuel	**TPES**	**Electricity**
Coal	3.81%	2.13%
Oil	29.21%	0.37%
Gas	13.32%	2.33%
Nuclear	46.49%	77.37%
Renewable	7.17%	17.8%
Tot	*244,637 ktoe*	*564,154 GWh*

Note that in France, nuclear energy represented more than 77% of total electricity power plant production in 2014, the world's highest share of nuclear in electricity mix (about 437 TWh). However, this share is expected to fall to 50% by 2025. As described in Section 1.13, the innovative process is tied with the dynamic of energy efficiency (η). In the productive sectors, demand (in Mtoe) for energy is given by $E_i^d = y_i/\eta_i$, where y_i is the total industry output.

There of the aggregated industries in the EUROGREEN model provide energy for final use: Electricity and Gas (ELG) and Fossil Fuels (C19). The former provides the whole electricity and gas in the economy, while the latter furnishes all the remaining fossil fuels needed in productive activities from the other industries. Total energy supply is then covered by these two industries, so that $E^i = E_i^{ELG} + E_i^{C19}$, where $E_i^{ELG} = E_i^{ELG,el} + E_i^{ELG,gas}$ and $E_i^{C19} = E_i^{C19,coal} + E_i^{C19,oil}$.

The technical coefficients of the input-output matrix are affected by technological progress through the change in η and in the energy mix (i.e., the composition of fuels for energy production). Thus, if the share of fossil fuels bought by firms reduces, then we would observe a reduction in the intermediate trade from C19 to other industries. From the Input-Output tables we recover the amount of intermediate sales from the two energy industries to all other ones, including intra-sectoral exchanges (e.g., electricity used to produce electricity). The monetary amount of inter-sectoral trade from seller i to the buyer j is defined as $Z_{i,j}$. For the two energy industries we rewrite it as the product of the unitary price of the source (p_e) and the total (physical) amount of energy traded, namely $Z_{i,j} = p_e \cdot E_{i,j}$. Note that since the two industries supply four sources of energy, then p_e represents an average price of all the types of energies supplied. Hence, their technical coefficients can be written as:

$$a_{i,j} = \frac{Z_{i,j}}{y_i} = \frac{E_{i,ji}}{y_i} \cdot p_e \qquad j\epsilon\{ELG, C19\}. \tag{65}$$

The total amount of energy bought by each sector (E_j) can be further decomposed by energy source. Then, $E_j = E_{ELG,j} + E_{C19,j}$ that can be rewritten in terms of share of energy source as:

$$E_j = (\gamma_j^{oil} + \gamma_j^{coal})E_j + (\gamma_j^{gas} + \gamma)j^{el})E_j = (\gamma_j^{C19})E_j + (\gamma_j^{ELG})E_j \tag{66}$$

where $\gamma_j^{oil} + \gamma_j^{coal} + \gamma_j^{gas} + \gamma_j^{el} = 1$. Hence, given the change in the energy mix, in the energy efficiency, and energy prices we obtain the dynamic of the technical coefficients of the two energy industries as:

$$a_{ELG,j} = p_{ELG} \frac{\gamma_{ELG,j}}{\eta_j} \tag{67}$$

$$a_{C19,j} = p_{C19} \frac{\gamma_{C19,j}}{\eta_j} \tag{68}$$

In this way, it is possibly to directly link the effect of technological progress (i.e., more energy-saving equipment) with the industry production-mix that is described by the technical coefficients.

Fossil energy and Electricity are also demanded by *households*. Households' consumption module determines the consumption expenditure level in the energy sector. For the sake of simplicity, we assume that the share of energy consumption expenditure going to each source is exogenous. The quantity of energy will change according to change in energy efficiency and the eventual public expenditure in ecological activities via job guarantee.

Production of **electricity** considers four sources. We assume that the shares of each energy source are exogenous. This does not mean that they are constant. We model the impact of the objectives of the Energy Transition for Green Growth Act of 17 August 2015. According to this official document, France should meet the following targets (IEA, 2016, p. 23):

- reduction of greenhouse gas (GHG) emissions by 40% in 2030 and by a factor of 4 towards 2050 (compared to 1990);
- reduction of final energy consumption by 20% in 2030 and 50% in 2050 (compared to 2012);
- renewable share of 32% in gross final energy consumption and 40% of total electricity generation by 2030;
- reduction of fossil fuel consumption of 30% by 2030 (in comparison to 2012);
- reduction of nuclear share in the electricity mix down to 50% by 2025 (from 78% today) and capping the installed capacity of nuclear power at the current level of 63.2 GW.

Finally, table 13 breaks down the initial energy consumption by industry and source simulated in the model.

The total energy consumption by energy source in the baseline scenario of the EUROGREEN model is presented in table 14 for selected years. It is also compared to the values projected in the 2016 EU reference scenario to 2050. Although the values are very similar for 2020 their difference grows over time. Our baseline simulation projects lower energy consumption from all but solids by 2050. Those difference may be attributed to the significantly lower GDP growth rates projected in out model with respect to most of the EU official projections, as seem in the comparison table presented in the main text.

Table 13: Energy mix by Industry. TPES in ktoe (of oil equivalent) by industry and composition by source of energy. Source: *Eurostat* - Energy Balances (own calculations). Note that the actual TPES for France in 2014 was 248,648 ktoe and the difference is due to the excluded sector "Households as employers".

EUROGREEN	Tot (ktoe)	coal	oil	gas	elect.
Agriculture	*4,538*	0,00%	76,33%	3,77%	19,90%
Mining	*169*	0,00%	48,52%	14,79%	36,69%
Fossil Fuel	*5,273*	20,57%	14,94%	4,68%	58,26%
Manufacturing	*40,728*	10,10%	35,74%	28,06%	22,98%
Electricity	*85909*	2,43%	3,03%	4,35%	90,20%
Construction	*1,027*	0,00%	57,35%	24,73%	17,92%
Services	*49,535*	0,00%	91,78%	0,19%	8,03%
Finance	*2,362*	0,77%	11,59%	30,48%	57,16%
Public	*18,671*	0,77%	11,59%	30,48%	57,16%
TOT	***208,212***	**3,58%**	**33,61%**	**10,74%**	**51,42%**

1.16 CO_2 Emissions

The energy demanded for production and final consumption have an environmental impact through CO_2 and other greenhouse gas emissions. In what follows the relationship between energy use and carbon emissions is presented through an empirical analysis of its drivers. Since the new input-output tables do not include an environmental matrix, we use the old version with a different industry aggregation with respect to the EUROGREEN model. In spite of this discrepancy, this decomposition analysis clarifies how structural change, modelled in our input-output structure, can affect emissions.

We use a Structural Decomposition Analysis (SDA) to break down France's yearly CO_2 emissions variation in 7 key drivers.[45] Before going ahead let us define the *Leontief technique*: the mathematical procedure that allows to recovery of the total effects due to a change in the final demand of a specific industry. It considers both the direct and the indirect sectoral linkages that can be further decomposed into the effects of a change in the product-mix (LH, or technology of production) and of a change in international trade (LT).

The existing literature agrees that this dynamic has been driven by a variety of factors such as changes in "carbon efficiency" (IE), structural change, composition of final demand and scale effects (Xu and Dietzenbacher, 2014). Here, we dig deeper into these drivers through the structural decomposition analysis (SDA) which is a particularly useful tool to evaluate the likely impact of demand-side change (and shocks) as it is based on the demand-driven Leontief model.

From a methodological perspective, SDA offers a static comparative analysis that allows to quantify the variation in energy requirements because of a change in one of the drivers while keeping all the others unchanged (i.e., ceteris paribus condition). The relative change of total CO_2 from time t to $t+1$ is a function of the following drivers:

[45] See (20) and (7) for a description of the structural decomposition analysis with Input-Output tables and its application for Water and CO_2 emissions.

Table 14: Energy consumption by source

Sources	2020	2030	2040	2050
Solid	8,234	7,545	6,242	4,918
	8,492	*5,012*	*3,116*	*2,134*
Oil	80,246	78,676	67,375	51,731
	75,372	*71,292*	*68,998*	*66,983*
Gas	38,800	36,340	28,840	22,076
	35,944	*32,194*	*36,029*	*33,460*
Electricity	130,500	118,000	92,840	70,290
	129,034	*128,035*	*111,330*	*105,323*

Comparison of energy consumption by source (in KTOE) in the Baseline scenario as simulated in the EUROGREEN model (black) and in the EU reference scenario 2016: energy, transport and GHG emissions trends (Mt of CO_2 eq.) to 2050 (blue/italic).

$\Delta CO_2 = \xi(IE; T; H; POP; MIX; CAP; DT)$. The intensity effect ($IE$) refers to changes in CO_2 per unit of output, T, and H represent the effects of trade and a change in the industry composition of intermediate inputs, respectively, captured by the Leontief inverse. The impact of final demand is decomposed into four components: international trade (*DT*), change in the product mix (*MIX*), and change in consumption (or income) per capita (*CAP*) and population size (*POP*).

Figure 2 shows the cumulative contribution to changes in CO_2 emissions of each component with respect to the base year (1995). The IE component describes the role played by changes in the vector of direct emissions of produced output, that is, it describes how changes in emissions in all countries affect the total emissions of a specific country. The contribution of this component has been rather small in the first years of the series (1995-2002) and then accelerated substantially until 2009.

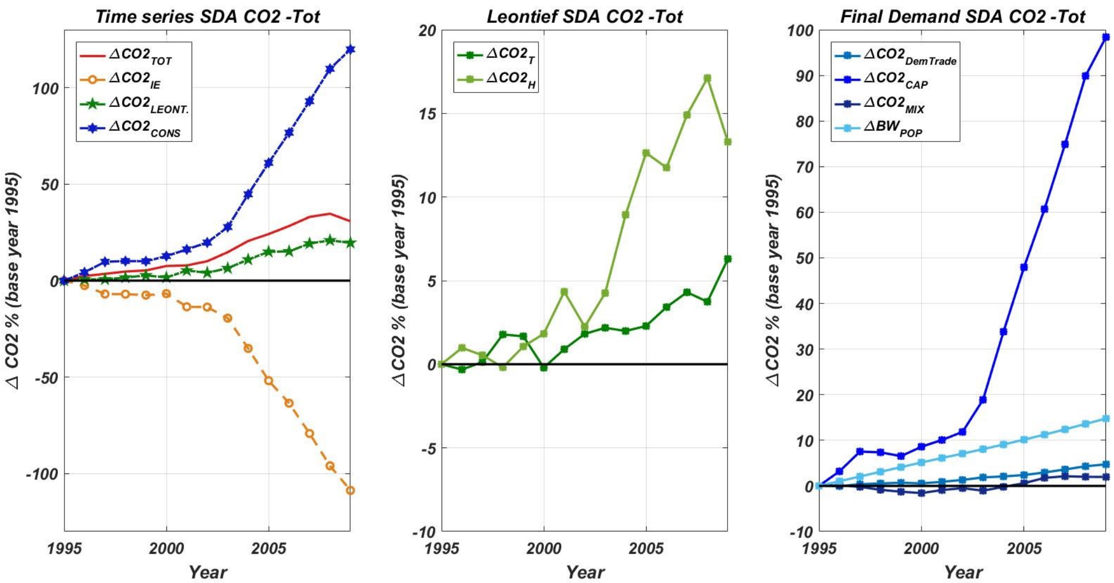
The central panel of Figure 2 shows in more details the impact related to intermediate goods. The component H should be interpreted as the contribution to emissions of changes in the mix of intermediate inputs with no consideration of the geographical origin of intermediate inputs. A positive sign reveals a systematic increase in the relative importance of CO_2-intensive sectors. Overall, this component has driven up the world emissions by about 15% over the period 1995-2009. The component T accounts for changes in the 'geographical' composition of the mix of intermediate inputs for a fixed average mix of intermediates (i.e., *LH*). A positive sign should be interpreted as a systematic shift of the purchase of intermediates towards more CO_2-intensive (in terms of average) countries. At the aggregate level, this component is very small (5%) and contributed positively to pollution.

The right panel of Figure 2 shows in more details the impact on emissions related to the four components of final demand. The first two components, MIX and DT, are the counterparts for final demand of the components LH and LT, respectively. The component MIX quantifies the role played by changes in the product mix of final demand for a given level of final demand and for a given 'geographical' composition of final demand. We find that it had almost no role in the time window considered. The DT component contributed (slightly) positively to the overall emissions (about 5%). The last two components refer to more aggregate driving forces: changes in total final demand per capita (in real terms) and demographic growth. The role played by changes in CAP, which is strongly correlated with affluence, is very important. Final demand per capita is by far the largest component that drives CO_2. Population showed a further positive impact of about 15%.

In the EUROGREEN model we recover greenhouse gas emissions,[46] by source and sector, from the Eurostat

[46]Greenhouse gases includes direct CO_2 and all the other air pollutants (N_2O, CH_4, HFC, PFC, SF_2, and NF_3) in CO_2

Figure 2: Structural decomposition analysis of the total CO2 emissions



(a) left panel includes the three main categories: carbon intensity (*IE*), Leontief effect (Leont.) and final demand (Cons.), (b) central panel decomposes the Leont. effect in *T* (international trade) and *H* (product-mix), and (c) right panel decomposes Cons. in international trade (*Dem. Trade*), income per capita (*CAP*), consumption mix (*Mix*), and population growth (*Pop*), from 1995 to 2009.

database. [47] Since we aggregate fuels in solid, liquid, and gas, we convert their physical amount of energy in CO_2 emissions. Data for conversion were taken from the Réseau de transport d'Électricité (*RTE*), [48] that provides the following factor of conversion in tons of CO_2 per unit of energy (*MWh*): 0.96 t/MWh for solid, 0.67 t/MWh for oil, and 0.46 t/MWh for gas.[49] Total CO_2 emissions are either subject to the carbon taxes described in the main text ot allocated to the EU-ETS. The freely allocated allowances of firms belonging to the EU-ETS, in France in 2014, were about 80,458 kton of CO_2 equivalent, while their actual emissions were around 114,547 kton. [50]

1.17 Public sector

The public sector (or, equivalently, government sector) in EUROGREEN corresponds to the general government sector (S13) in the national accounts. That is, it excludes public corporations, and with them most of the market output of the real-world public sector. By definition, S13 produces mainly non-market output, i.e., output provided to others "free of charge or at prices that are not economically significant, meaning in practice prices that cover less than half

equivalent.

[47]see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_air_gge&lang=en

[48]See https://www.rte-france.com/fr/eco2mix/eco2mix-co2.

[49]Note that, in order to be consistent with the industry emissions provided by Eurostat, this have been updated (taking constant the proportions) depending on the sector.

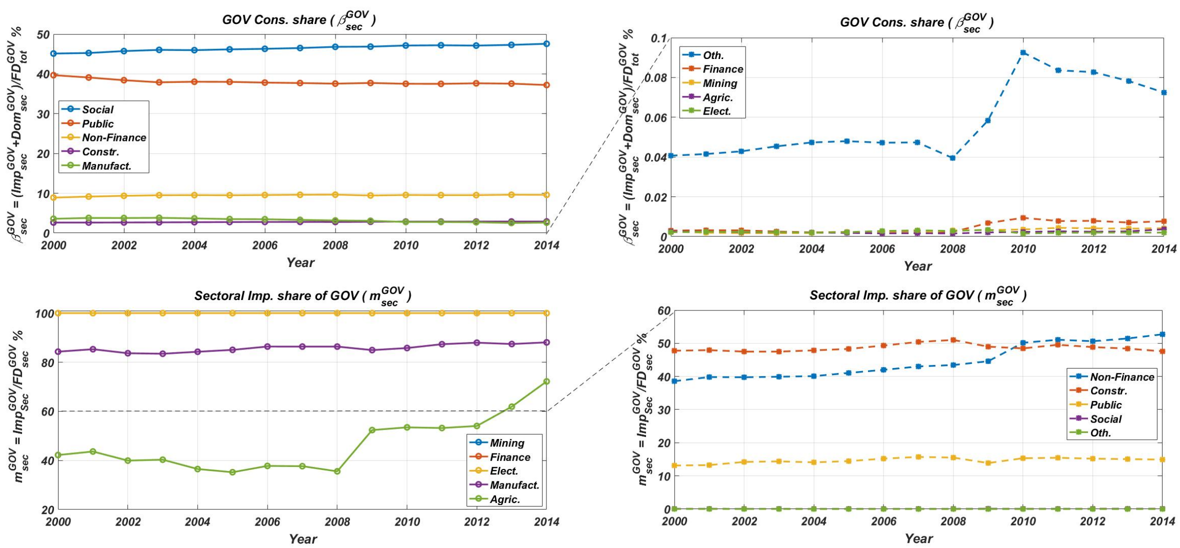
[50]see https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1, while the total emissions from the NACE sectors was 326,155 kton.

the cost of production" (15, p. 114). In national accounting, non-market output is measured at cost, equal to the sum of labour compensation, intermediate consumption, and consumption of fixed capital (15, p. 280).[51] The operating surplus (i.e., profits) is virtually zero, due to the exclusion of for-profit public corporations. A further peculiarity of S13 is that its non-market output is largely consumed by itself. As (15, p. 281-282) explain: "because there are no observable monetary transactions (the services are free of charge), national accountants have given up on the idea of attributing this consumption specifically to households or to firms, and they have attributed it to general government itself."

1.18 Government expenditure and revenue

Fig. 3 shows the historical time series of the share import and domestic consumption for government, by industry. As in case of households, this ratios are remarkably stable throughout the period (2000-2014). The only exception are purchases of government from foreign agricultural firms. After the global financial crisis it appears the French government increased its imports of agricultural commodities. Note that these ratios do not indicate the magnitude of the government sectoral expenditure,[52] but they are used to calibrate the model and to justify the assumption of constant import coefficients.

Figure 3: *Time series of the share of import (m) and sectoral (β) consumption for each sector, for Government, from 2000 to 2014, in France. Source: WIOD 2016 (own estimations).*



Government **consumption** [53] is defined as G^C and is composed by government expenditure in job guarantee

[51] In 2014, non-market output represented 87.4% of the total output of S13, the remainder being market output which "consists of sales by the general government (publications, sales of medicines by hospitals, exports of warships from naval shipyards, sales of water supply by communal syndicates)" (15, p. 282).

[52] For instance, it results that the total amount of energy used by the government is imported. However, in absolute terms, the expenditure is relatively low, in the range €7-22 million in the time window considered (2000–2014).

[53] To be precise, we should refer to the component S13 of the NIOT. Following the conventions of national accounting, the non-market output (P13) of the public sector is assumed to be consumed by the public sector itself, except for partial payments by households. Government consumption of goods and services produced by the market sector is labelled D632. Non-market output (P13), net of partial payments (P131) amounted to about 387,541 million of euro (75% of S13 consumption), while the remaining part was spent in social transfers in kind - purchased market production (D632),

(G^{JG})[54], government expenditure in investments (G^K), government expenditure in transfers (G^{Tr}), government expenditure in wages (G^w), payments of interests on bond (G^B), and nominal expenditure in final goods (G^f). Hence, $\mathbf{G}^C = G^f + G^B + G^w + G^{Tr} + G^K + G^{JG}$. The main inflows of government are **taxes** (G^T), such as: employers' social contributions (G^{D12}), tax on value added (G^{VAT}), corporate income taxes (G^{CIT}), tax on wealth (G^V), households' taxes (G^{HH}), carbon tax (G^{CARB}), and border carbon adjustment (G^{BCA})[55]. Hence, $\mathbf{G}^T = G^{D12} + G^{VAT} + G^{CIT} + G^{HH} + G^V + G^{CARB} + G^{BCA}$. The difference between this two component returns the yearly public **deficit**: $\mathbf{G}^D = G^C - G^T$.

The list of government's sources of expenditure and revenue is summarizes in table 15 and explained in greater detail throughout the rest of this section.

Table 15: Government Balance: revenue and expenditure.

Expenditure	**Revenue**
Government consumption	Value added tax
Wages	Labour taxes
Investment	Corporate income tax
Interest on public debt	Progressive income tax
Pensions	*Contribution sociale généralisée*
Unemployment benefits	*Remboursement de la dette sociale*
Sickness and disability benefits	Aggregate social contribution
Family and children benefits	Tax on financial income
Revenu de Solidarité Active	Wealth tax
	Carbon taxes

On the *expenditure* side:

- G^{Tr} is the total expenditure in social transfers for unemployed, pensioners, out-of-the-labour force individuals, and other social protection transfers (see subsections 1.6.1, 1.6.2, and 1.6.3, respectively);
- G^w is gross wage bill of employed workers in public sector;
- G^K are the investments in gross fixed capital formation needed to cover the depreciation of installed capital and for new equipment (see Section 1.14);
- G^B is the government's expenditure on debts (i.e., bond), as described by Eq. 74 below;
- G^f is the total final consumption, [56] including net of imports, which is assumed to grow at a constant yearly exogenous rate of 0.6%;
- G^{JG} is the total expenditure on the job guarantee policy whenever it is active, as described in Section 3 of the main text. This includes wages of newly hired workers that perform specific activities (e.g., social care, ecological services).

for about 128,136 million of euro in 2014.

[54]when the JG policy is simulated only.

[55]Once again, only whenever a carbon border adjustment tax on imports is simulated.

[56]From NIOT it results that the French total nominal public sector consumption, in 2014, was around €514 billions.

The components of *tax* revenue are the following:

- G^{D12} are the inflows from employers' social contributions which are payed on the gross wage bill of each industry (i.e. $t^{LAb} \cdot GWB_{i,j}$); [57]
- G^{VAT} is the value added tax, by industry;[58]
- $G^{C}IT$ is the total corporate income tax (Impôt sur les sociétés), by sector. The standard rate is 33.3% of taxable income (28% for up to €500,000 in profits).[59] It will be reduced to 28% in 2020, and to 25% in 2022. [60]
- G^{HH} is the overall revenue from all taxes payed by households: type A and B taxes, compulsory social security contributions (tax D613), and taxes on financial gains (where the tax rate is 30%).
- G^{V} is based on the European wealth tax (EWT, national accounts indicator D59A).
- G^{CARB} and G^{BCA} are the environmental taxes imposed to curb greenhouse gas emissions, as described in the main text. Taking into account the recent French National Energy Transition for Green Growth program, which introduced a carbon tax of €7 per ton of CO2 in 2014. The tax rates increase about €8 per ton of CO_2 per year until 2020 up until €56 in 2020 and €100 per ton of GHG emissions in 2030.[61] The second fiscal instrument introduced is a border carbon adjustment tax that imposes the same carbon tax rates to imports according to their GHG content with the sole exception of agricultural imports.

1.19 Government finance

This Section explains the modelling of the government *bond* market. The nominal demand for bonds is determined by the portfolio choice model (see Section 1.8). French long-term government bonds (B) are the only type of bonds included in EUROGREEN. Therefore, the total nominal demand for French government bonds is:

$$B^d = B_M + B_H + B_{Kp}. \tag{69}$$

According to our calculations based on WID.world data, the total nominal stock of bonds (of any kind) held by resident adults in France in 2014 was €632,498 million. The Maastricht-reported [62] public debt of France at the end of 2014 was €2,040,379 million, of which €1,705,069 million in debt securities, further divided into €196,824 million in short-term bills (original maturity up to 1 year) and €1,508,245 million in long-term bonds (original maturity over 1 year or no stated maturity) (ECB).[63] Of the total debt securities, €883,489 million were held by resident sectors, and the remaining €821,580 million held by the foreign sector.

[57] The tax D12 rate varies across industries, but are assumed constant over time. In particular, the values applied in the simulations, where in bracket there is the number of the corresponding EUROGREEN sector, are: (1) 43.13%, (2) 39.91%, (3) 69.87%, (4) 37.2%, (5) 81.71%, (6) 25.96%, (7) 31.86%, (8) 43.55%, (9) 50.65%, and (10) 17.06%.

[58] The VAT tax rate varies across industries, but are assumed constant over time. In particular, the values applied in the simulations, where in bracket there is the number of the corresponding EUROGREEN industry, are: (1) 4.5%, (2) 10%, (3) 20%, (4) 15%, (5) 20%, (6) 12%, (7) 17.7%, (8) 20%, (9) 5.5%, and (10) 10%.

[59] See "Recent Developments In French Taxation", https://www.lexology.com/library/detail.aspx?g=7eea49a3-3272-4855-a8eb-58ca33a2e6a2.

[60] Finance Minister Bruno Le Maire "said corporate tax would be cut to 31 percent in 2019, 28 percent in 2020, 26.5 percent in 2021 and 25 percent by the end of Macron's term in 2022." (Reuters, "French government outlines gradual corporate tax cut plans", https://www.reuters.com/article/us-france-reform/french-government-outlines-gradual-corporate-tax-cut-plans-idUSKCN1BA2HX.

[61] See law no. 2015-992 on Energy Transition for Green Growth.

[62] Maastricht-reported public debt is the consolidated debt valued at face value (15, p. 292).

[63] In France, long-term bonds are known as Obligations Assimilables du Trésor (OAT), and short-term bills are Bons du Trésor à taux fixe et á intérêrets précomptés (BTF). See Agence France Trésor, http://www.aft.gouv.fr/rubriques/general-information_169.html.

In order to focus the model on the policy issues considered, the bond market is assumed to be in initial equilibrium. For this purpose, we scale the outstanding stock of debt securities (i.e., the supply of bonds, B^S) to the demand for bonds:

$$B^s = \frac{1705069}{632498} B^d = 2.69577 B^d \tag{70}$$

The modelling of the bond market is loosely based on Burgess et al. (2016). The government determines the outstanding stock of bonds in volume, $\overline{B}$, such that the budget deficit is covered if the bonds sell at the government's expected price, $E(p_{B,t}) = p_{B,t-1}$. The shortfall (or excess) of funds caused by mistaken expectations is covered by the issuance (or withdrawal) of short-term bills, which do not bear interest by assumption. All short-term bills outstanding are redeemed after one period. Thus, the stock of long-term bonds outstanding at the end of period t, measured in volume, is equal to the stock at the end of the previous period, minus net lending, $B9_{S13}$, converted into expected volume, plus short-term bills Bl outstanding at the end of the previous period, also in expected volume:

$$\overline{B}_t = \overline{B}_{t-1} + \frac{B9_{S13} + Bl_{t-1}}{E(p_{B,t})} \tag{71}$$

The price on long-term bonds adjusts to clear the (scaled) market: $p_B = B^s/\overline{B}$.

For clarity (although the equation is not used in the model), we derive the realized value of the new bond issue as:

$$\Delta B^s_t = p_{B,t}(\Delta \overline{B}_t) = B^s_t - \frac{p_{B,t}}{p_{B,t-1}} B^s_{t-1} \tag{72}$$

Thus, the supply of short-term bills is equal to the excess of the expected over the realized value of the issue:

$$Bl_t = E(p_{B,t}) \Delta \overline{B}_t - \Delta B^s_t. \tag{73}$$

Due to our assumption of initial equilibrium on the bond market, the stock of short-term bills outstanding at the end of 2014 is assumed to be zero, so that the nominal stock of long-term bonds is equal to the €1,705,069 million for total debt securities. Thus, the quarterly rate of interest on government bonds is:

$$nr^B_t = nr^B_{t-1} - 0.000166925 \Delta P_{B,t} \tag{74}$$

Following (13, chapter 5), bonds are modelled as perpetuities that are never redeemed. The pre-tax rate of return on bonds, including real capital gains, is:

$$rr^B_t = \frac{\Delta p_{B,t}}{p_{B,t-1}} - \frac{\Delta CPI_t}{CPI_{t-1}} + nr^B_t \tag{75}$$

where CPI is the consumer price index. Finally, the post-tax rate of return, which enters the portfolio choice model, is:

$$nrr^B_t = (1 - t^F) rr^B_t \tag{76}$$

where t^F is tax rate on financial income (set to 30%).

1.20 Interest rates

The basic interest rate is determined in the model according to a Central Bank reaction function. Departing from the actual average EONIA (Euro overnight index average) rate for 2014 of 0.02% the Central Bank increases this basic rate as a positive function of deviations of the consumer price index from the yearly target of 2%. However, since the model simulates the french economy exclusively we assume that the reaction function depends on national inflation only and not on the Euro area inflation rate as the European Central Bank actually does.

$$EONIA_t = EONIA_{t-1} + d^{BCE}(\Delta CPI_{t-1} - 0.02) \tag{77}$$

Where d^{BCE} is the Central Bank sensitivity to deviations from the target, set to 1.25. The interest rate paid on private debt by industries is then set to move together with the basic rate starting from the actual average value in 2014 of 0.7%.

$$i_t = max[i_{t-1} + 0.201806(d^{BCE}(\Delta CPI_{t-1} - 0.02)) + 0.335394(d^{BCE}(\Delta CPI_{t-2} - 0.02))] \tag{78}$$

2 Summary of Simulated Policies

The following four tables present a concise summary of the single policies simulates in the model (tables 16, 17 and 18) and of the three policy mixes they compose (table 19) presented in the main text.

3 Scenario Analysis: single policies

This section of provides further details on the simulation results with single policies summarized in the previous section. The graphs in Figure 4 plot the effects of these single policies on the main objective variables of the model: GDP growth, GDP per capita, unemployment rates, government's deficit-to-GDP ratio, the labour share on functional income distribution, GINI coefficient, energy efficiency and GHG emissions.

We opted for the *Job Guarantee* instead of *Basic Income* (*BI*) as part of the *PSE* and *DG* policy-mixes because the former directly faces the problem of unemployment seems to perform better than the latter on its own with long-lasting effects on employment and distribution due to the continued hiring of workers into the program. Moreover, the cost of a *BI*, even when assuming relatively small yearly benefit (€5, 580), has a much larger impact on government deficit than the *Job Guarantee* program, as seen in the south-east quadrant of figure 4a.

References

[1] Basic income as a policy option: Technical background note illustrating costs and distributional implications for selected countries.

[2] Acemoglu, D., and Autor, D. Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of labor economics*, vol. 4. Elsevier, 2011, pp. 1043–1171.

[3] Brainard, W. C., and Tobin, J. Pitfalls in financial model building. *The American Economic Review 58*, 2 (1968), 99–122.

[4] Browne, J., and Immervoll, H. Basic income as a policy option: Can it add up? *Policy Brief on the Future of Work, OECD* (2017).

[5] Commission, E. The 2015 ageing report: Economic and budgetary projections for the eu28 member states (2013-2060).

[6] Commission, E. The 2015 ageing report: Underlying assumptions and projection methodologies.

[7] Distefano, T., Riccaboni, M., and Marin, G. Systemic risk in the global water input-output network. *Water Resources and Economics* (2018).

[8] ENGEL, C. Long-run ppp may not hold after all. *Journal of International Economics 51*, 2 (2000), 243–273.

[9] FLOOD, R. P., AND ROSE, A. K. Uncovered interest parity in crisis. *IMF staff papers 49*, 2 (2002), 252–266.

[10] FREITAS, F., AND SERRANO, F. Growth rate and level effects, the stability of the adjustment of capacity to demand and the sraffian supermultiplier. *Review of Political Economy 27*, 3 (2015), 258–281.

[11] GARBINTI, B., GOUPILLE-LEBRET, J., AND PIKETTY, T. Accounting for wealth inequality dynamics: Methods, estimates and simulations for france (1800-2014). *Banque de France Working Paper*, 633 (2017).

[12] GIRARDI, D., AND PARIBONI, R. Long-run effective demand in the us economy: An empirical test of the sraffian supermultiplier model. *Review of Political Economy 28*, 4 (2016), 523–544.

[13] GODLEY, W., AND LAVOIE, M. *Monetary economics: an integrated approach to credit, money, income, production and wealth*. Springer, 2016.

[14] GOOS, M., MANNING, A., AND SALOMONS, A. Job polarization in europe. *American economic review 99*, 2 (2009), 58–63.

[15] LEQUILLER, F. Towards convergence between government finance statistics and public sector accounting standards. *EUROSTAT REVIEW ON NATIONAL ACCOUNTS AND MACROECONOMIC INDICATORS* (2015), 19.

[16] OECD. Pensions at a glance 2013.

[17] OECD. Taxing wages 2015.

[18] SPRONK, R., VERSCHOOR, W. F., AND ZWINKELS, R. C. Carry trade and foreign exchange rate puzzles. *European Economic Review 60* (2013), 17–31.

[19] TOBIN, J. A general equilibrium approach to monetary theory. *Journal of money, credit and banking 1*, 1 (1969), 15–29.

[20] XU, Y., AND DIETZENBACHER, E. A structural decomposition analysis of the emissions embodied in trade. *Ecological Economics 101* (2014), 10–20.

Table 16: Summary of Single Policies: High Labour Productivity (HLP), Energy Efficiency (HEEF), Basic Income (BI), Job Guarantee (JG).

Policy	Summary	Comment	Real per capita GDP	GHG emissions	Unemployment	Income inequality	Deficif GDP
HLP	Reduces the labour saving innovation threshold parameter from 0.75 to 0.6 and the joint labour and energy saving threshold from 0.8 to 0.65	Average labour productivity increases about 25% more than in the baseline scenario	~ 0	$-$	$+$	$+$	~ 0
HEEF	Reduces the energy saving innovation threshold parameter from 0.5 to 0.3	Average energy efficiency increases about 16% more than in the baseline scenario	~ 0	$-$	~ 0	~ 0	~ 0
BI	Introduces a 5,580 yearly benefit to all working age adults that substitutes or reduces other social transfers	A high initial impact on growth a income distribution dissipates in time while deficit remains relatively high.	$+$	$+$	$-$	$-$	$+++$
JG	Government hires a maximum of 300,000 unemployed workers per year that perform either services or environmental work and are paid the minimum wages	Due to gradual hiring **JG** has a continued impact on employment and income distribution.	$+$	~ 0	$--$	$--$	$++$

The effects of each policy/parameter on selected indicators is represented by $+$ and $-$ which indicate an increase (decrease) of that indicator with respect to the baseline scenario. The signs do not indicate improvement ($+$) and worsening ($-$) of the indicators, but rather represent a numerical increase of decrease. Hence, while a $++$ in real per capita GDP might be interpreted as an improvement the same sign in greenhouse gas emissions is certainly an undesired effect of a policy. The symbol ~ 0 represents a negligible effect on the indicator.

Table 17: Summary of Single Policies: Working Time Reduction (WTR), Energy Mix (EnM) and Border Carbon Adjustment (BCA).

Policy	**Summary**	**Comment**	**Real per capita GDP**	**GHG emissions**	**Unemployment**	**Income inequality**	**Deficif GDP**
WTR	Weekly working hours are reduced from 35 to 30	Reduction leads industries to increase hiring, particularly in the five years in which the policy is introduced.	−	−	−	−	−
EnM	Gradually substitutes fossil fuels and nuclear power for renewables in electricity production while increasing the share of electricity in total energy consumption	Despite being by far the most effective environmental policy, it only has a mild impact on the other main indicators	~ 0	− − −	−	−	~ 0
BCA	Additional yearly increases of 4.4% in carbon tax rates after 2030 and application of similar taxes on imports CO2 content	Overall carbon taxes have a small impact on the simulations, mostly due to the limited amount of emissions that are subject to the taxes	~ 0	~ 0	−	−	~ 0

The effects of each policy/parameter on selected indicators is represented by $+$ and $-$ which indicate an increase (decrease) of that indicator with respect to the baseline scenario. The signs do not indicate improvement ($+$) and worsening ($-$) of the indicators, but rather represent a numerical increase of decrease. Hence, while a $++$ in real per capita GDP might be interpreted as an improvement the same sign in greenhouse gas emissions is certainly an undesired effect of a policy. The symbol ~ 0 represents a negligible effect on the indicator.

Table 18: Summary of Single Policies: Consumption Reduction, Export Reduction, Wealth Tax.

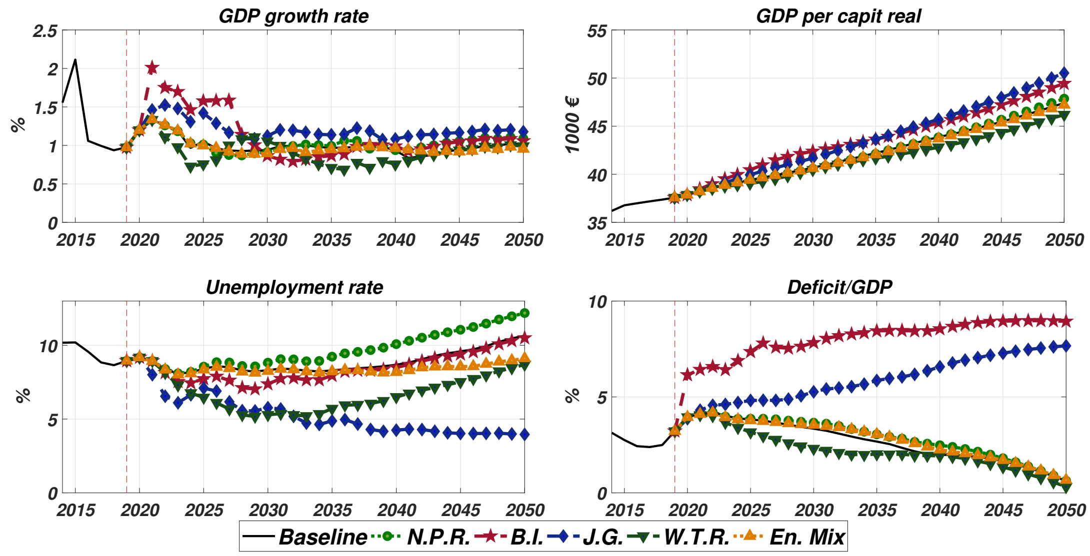
Policy	Summary	Comment	Real per capita GDP	GHG emissions	Unemployment	Income inequality	Deficit GDP
CR	Yearly reduction of 1.6% in marginal propensities to consume between 2020 and 2050	By 2050 **CR** results in a meaningful reduction of total private consumption and a relevant ,though indirect, reduction in emissions and increase in unemployment	$---$	$-$	$++$	$+$	$+++$
XR	Yearly reduction of 0.05% of exports between 2020 and 2050	Effects are similar to **CR** but weaker. **XR** serves mostly to contain an undesired increase in emissions from **CR** due to internal price reduction which favor exports	$--$	$-$	$+$	$+$	$++$
CR + XR + WTax	**CR+XR** together with an increase in the wealth tax rate proportional to the fall in average propensities to consume	The joint increase of wealth tax rates, up to around 1.5%, help contain the increase in deficit-to-GDP ratio that follows consumption reduction.	$---$	$--$	$+++$	$++$	$--$

The effects of each policy/parameter on selected indicators is represented by $+$ and $-$ which indicate an increase (decrease) of that indicator with respect to the baseline scenario. The signs do not indicate improvement ($+$) and worsening ($-$) of the indicators, but rather represent a numerical increase of decrease. Hence, while a $++$ in real per capita GDP might be interpreted as an improvement the same sign in greenhouse gas emissions is certainly an undesired effect of a policy. The symbol ~ 0 represents a negligible effect on the indicator.

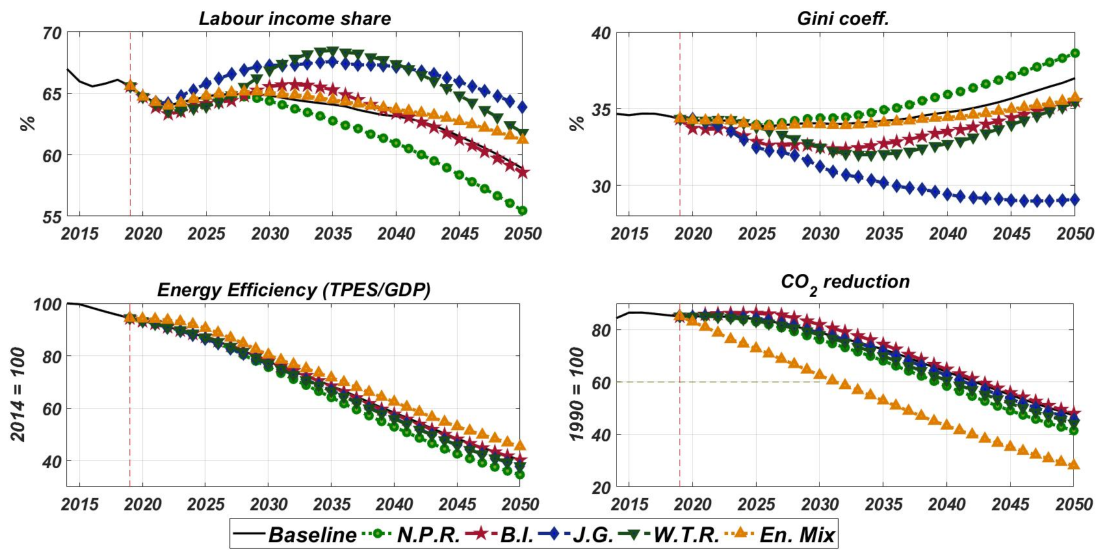
Table 19: Summary of Policy Mixes.

Scenario	Green Growth	Policies for Social Equity	De-Growth
Policy Mix	New Productive Revolutions + Energy Mix + Carbon Tax + ETS	Job Guarantee + Working Time Reduction + Energy Mix + Carbon Tax + ETS + High Energy Efficiency	Job Guarantee + Working Time Reduction + Energy Mix + Carbon Tax + ETS + High Energy Efficiency + Consumption + Export reduction + Wealth Tax
Comment	Main difference with respect to baseline is GHG reduction due to the energy mix. Improved fiscal performance comes at the expense of employment and inequality increases.	Sustains a similar GHG reduction similar to DG while avoiding increases in unemployment and inequality though at a higher fiscal cost.	Similar results to PSE. However, consumption reduction allows further GHG reduction while increased wealth tax mitigates the fiscal cost of this policy mix
GDP	−	+	− − −
Emissions	− −	− −	− − −
Unemployment	+	− − −	− −
Inequality	+	− − −	− − −
Deficit	−	+ + +	+ +

The effects of each policy mix on selected indicators are represented by + and − which indicate a numerical increase (decrease) of that indicator with respect to the baseline scenario. Whereas improvements (worsening) are marked in blue (red). The precise indicators listed above are: real per capita GDP (GDP), greenhouse gas emissions (Emissions), general unemployment rate (Unemployment), the gini coefficient (Inequality) and government's deficit-to-GDP ratio (Deficit).



(a) Economic indicators



(b) Income distribution and Environment

Figure 4: Scenario analysis from single policies. Panel (a) shows the main economic indicators, while (b) presents some environmental and income inequality indicators.