ENERGY & ENVIRONMENTAL POLICIES:
IMPACTS ON GROWTH AND INTERGENERATIONAL REDISTRIBUTIVE EFFECTS

FRÉDÉRIC GONAND – SÉMINAIRE PSL – 18 NOVEMBRE 2015

DAUPHINE UNIVERSITÉ PARIS | LEDa CGEMP EA 4404 | PSL RESEARCH UNIVERSITY

THE QUESTION

What are the impacts on GDP growth *and* on intergenerational inequality of energy policies?

(*e.g.*, recycled carbon tax, support to renewables, higher energy efficiency, regulated end-use prices / oil production levels…).

- A long-run issue

  -> potential growth, solovian models, general equilibrium
- A demographic & theoretical issue

  -> overlapping-generations (OLG) models -> dynamic general equilibrium
- An empirically treated issue

  -> parameterization on real data
- An economic policy issue

  -> modeling social choice
- A geography-dependent issue

  -> European countries / Gulf countries

WHAT DOES THE ACADEMIC LITERATURE SAY ON THIS ISSUE? (1/2)

- General equilibrium setting with energy (+environment): Böhringer and Rutherford (1997), Böhringer and Löschel (2006), Otto, Löschel and Dellink (2007)… / CGE models…

  However, literature often relies on static GE models that do not aim to account for intergenerational redistributive effects.

- -> GE with OLG: Bovenberg and Heijdra (1998), Karp and Resai (2014), Chiroleu-Assouline and Fodha (2006).

  However, literature often with theoretical approach + few generations + not mainly designed to analyze interactions between GE-CO2 nor social choice.

WHAT DOES THE ACADEMIC LITERATURE SAY ON THIS ISSUE? (2/2)

- -> empirical, dynamic GE with OLG+energy sector: much less literature. Carbone *et al.*, 2012 / Carbone *et al.*, 2013 / Rausch, 2013. Our model close to these references BUT with differences:
  - policies analyzed *(renewables, energy efficiency gains, carbon emissions);*
  - detailed demographics *(annual data, 60 cohorts);*
  - public finances (*e.g.*, different ways of recycling a carbon tax, public spending influenced by ageing…);
  - social choice (*e.g.*, optimal mix of policies, social welfare functionals…) (see Van der Ploeg and Withagen (2014) but without OLGs and no empirical parameterization).
  - parameterization on German & French data + another (modified) version on Saudi data (energy policies in oil exporting countries)(KAPSARC).

THE MODEL (1/3)

Cf. Gonand F. and P.-A.Jouvet, “The “second dividend” and the demographic structure”, *Journal of Environmental Economics and Management*, 72 (2015), 71-97.

General Equilibrium model with an energy module…

- Electricity (wholesale price, network costs, FiT…), oil products, natural gas, coal.
- Production function with K, L and Energy (nested CES function)

$$Y_t = \left[a\,(B_t E_t)^{\gamma_{en}} + (1-\alpha)\,[C_t]^{\gamma_{en}}\right]^{\frac{1}{\gamma_{en}}}$$

$$C_t = \left[\alpha K_t^{1-\frac{1}{\beta}} + (1-\alpha)\,[A_t \bar{\varepsilon}_t \Delta_t L_t]^{1-\frac{1}{\beta}}\right]^{\frac{1}{1-\frac{1}{\beta}}}$$

- Models the impact of variables in the energy sector on growth, savings, L supply, K per unit of efficient labor, substitution between K and energy…
- Long-run macro equilibrium. 1 good (no input-output matrix: not a CGE).

THE MODEL (2/3)

… with an overlapping generations framework (OLG)(60 cohorts)

$$U_{t,0}^{*}=\frac{1}{1-\sigma}\sum_{j=a}^{\Psi_{t,0}}\left[\frac{1}{(1+\rho)^{j}}\left[\left((c_{t+j,j}^{*})^{1-1/\xi}+\varkappa\left(H_{j}\left(1-\ell_{t+j,j}^{*}\right)\right)^{1-1/\xi}\right)^{\frac{1}{1-1/\xi}}\right]^{1-\sigma}\right]$$

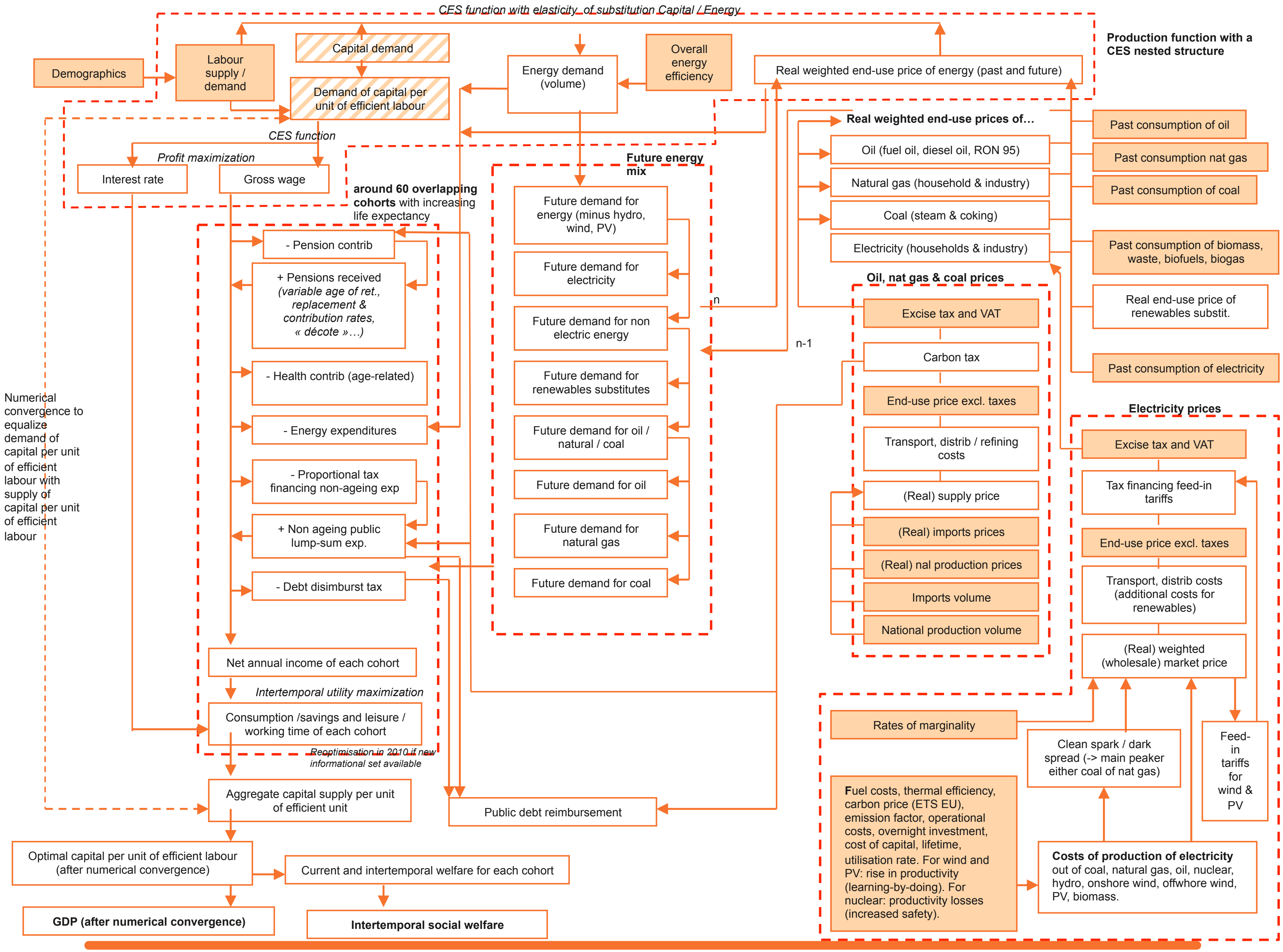
Constraint:

$$\ell_{t,0}^{*}\omega_{t,0}+\sum_{j=1}^{\Psi_{t,0}}\left[\ell_{t+j,j}^{*}\omega_{t+j,j}\prod_{i=1}^{j}\left(\frac{1}{1+r_{t+i}}\right)\right]=c_{t,0}^{*}+\sum_{j=1}^{\Psi_{t,0}}\left[c_{t+j,j}^{*}\prod_{i=1}^{j}\left(\frac{1}{1+r_{t+i}}\right)\right]$$

CPO (Euler equation): $\frac{c_{t,a}^{*}}{c_{t-1,a-1}^{*}}=\left(\frac{1+r_{t}}{1+\rho}\right)^{\kappa}\left(\frac{1+\varkappa^{\xi}\omega_{t,a}^{1-\xi}}{1+\varkappa^{\xi}\omega_{t-1,a-1}^{1-\xi}}\right)^{\frac{\kappa-\xi}{\xi-1}}$

… and public finances :

- Public spending (pensions; non ageing-related public expenditures…)
- Social contributions, income tax, carbon tax



CES function with elasticity of substitution Capital / Energy
Production function with a CES nested structure
Demographics
Labour supply / demand
Capital demand
Demand of capital per unit of efficient labour
Energy demand (volume)
Overall energy efficiency
Real weighted end-use price of energy (past and future)
CES function
Profit maximization
Interest rate
Gross wage
around 60 overlapping cohorts with increasing life expectancy
Future energy mix
Real weighted end-use prices of…
Oil (fuel oil, diesel oil, RON 95)
Natural gas (household & industry)
Coal (steam & coking)
Electricity (households & industry)
Past consumption of oil
Past consumption nat gas
Past consumption of coal
Past consumption of biomass, waste, biofuels, biogas
Real end-use price of renewables substit.
Past consumption of electricity
- Pension contrib
+ Pensions received (variable age of ret., replacement & contribution rates, « décote »…)
- Health contrib (age-related)
- Energy expenditures
- Proportional tax financing non-ageing exp
+ Non ageing public lump-sum exp.
- Debt disimburst tax
Future demand for energy (minus hydro, wind, PV)
Future demand for electricity
Future demand for non electric energy
Future demand for renewables substitutes
Future demand for oil / natural / coal
Future demand for oil
Future demand for natural gas
Future demand for coal
n
n-1
Oil, nat gas & coal prices
Excise tax and VAT
Carbon tax
End-use price excl. taxes
Transport, distrib / refining costs
(Real) supply price
(Real) imports prices
(Real) nal production prices
Imports volume
National production volume
Electricity prices
Excise tax and VAT
Tax financing feed-in tariffs
End-use price excl. taxes
Transport, distrib costs (additional costs for renewables)
(Real) weighted (wholesale) market price
Numerical convergence to equalize demand of capital per unit of efficient labour with supply of capital per unit of efficient labour
Net annual income of each cohort
Intertemporal utility maximization
Consumption /savings and leisure / working time of each cohort
Reoptimisation in 2010 if new informational set available
Aggregate capital supply per unit of efficient unit
Public debt reimbursement
Rates of marginality
Clean spark / dark spread (-> main peaker either coal of nat gas)
Feed-in tariffs for wind & PV
Fuel costs, thermal efficiency, carbon price (ETS EU), emission factor, operational costs, overnight investment, cost of capital, lifetime, utilisation rate. For wind and PV: rise in productivity (learning-by-doing). For nuclear: productivity losses (increased safety).
Costs of production of electricity out of coal, natural gas, oil, nuclear, hydro, onshore wind, offwhore wind, PV, biomass.
Optimal capital per unit of efficient labour (after numerical convergence)
Current and intertemporal welfare for each cohort
GDP (after numerical convergence)
Intertemporal social welfare

APPLICATION 1: THE SECOND DIVIDEND AND THE DEMOGRAPHIC STRUCTURE (1/5)

- Intuition:
  - The demographic structure influences macroeconomic activity.
  - The "second dividend" modifies growth (*environmental taxes may lessen the distortive effects of the tax system if they are substituted to income taxes or proportional social contributions. Recycling a carbon tax through lower taxes on labor income could trigger a higher effect on activity than through higher spending; for a survey: see Bovenberg and Goulder, 2002*).
  - Thus, in general equilibrium, the second dividend and the demographic structure should be interrelated.

Cf. Gonand F. and P.-A.Jouvet, "The "second dividend" and the demographic structure", *Journal of Environmental Economics and Management*, 72 (2015), pp.71-97.

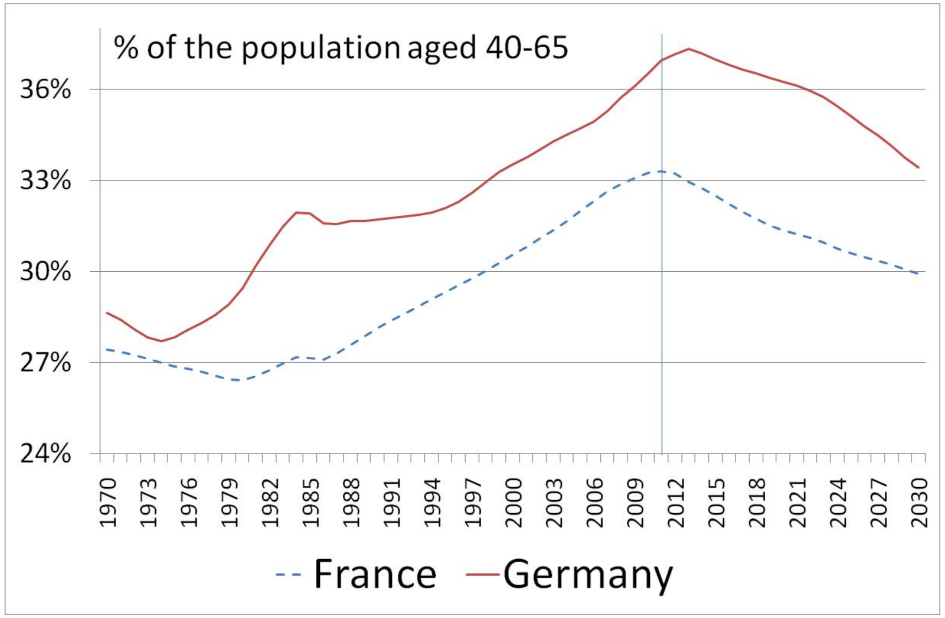
APPLICATION 1: THE SECOND DIVIDEND AND THE DEMOGRAPHIC STRUCTURE (2/5)

- Policy scenarios…

	Carbon tax redistributed through…	
	… higher lump-sum public expenditures	… lower proportional, direct income taxes
Germany	Scenario DEU EXP	Scenario DEU TAX
France	Scenario FRA EXP	Scenario FRA TAX

- … parameterized on two different demographic structures (*e.g.*, France and Germany).

  In line with life-cycle theory, the cohorts aged 40-65 save more than other demographic groups in the model. + they are on average more productive than the young active cohorts.

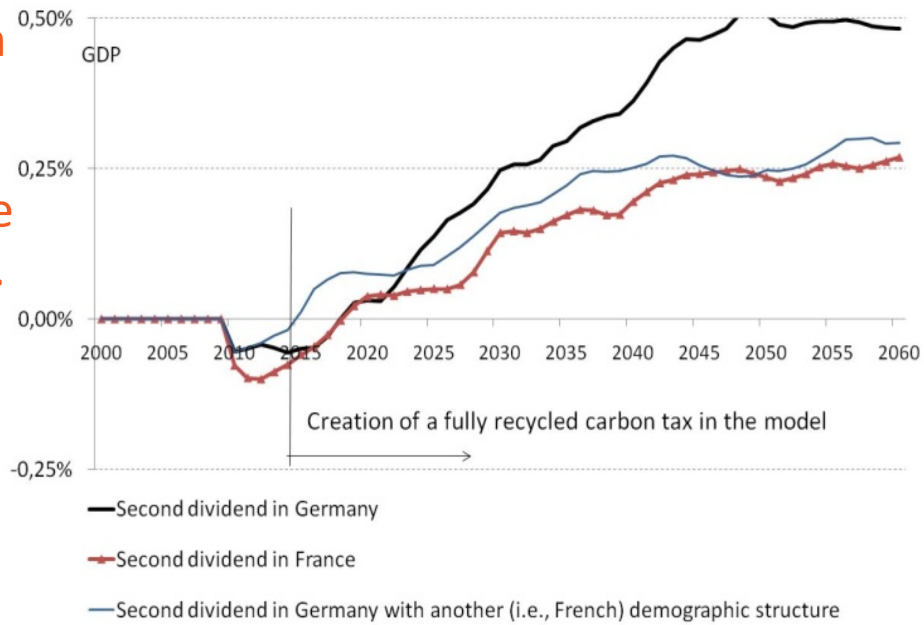


APPLICATION 1: THE SECOND DIVIDEND AND THE DEMOGRAPHIC STRUCTURE (3/5)

The second dividend is higher in the model for relatively older countries than for relatively younger ones, and the difference mirrors mainly the influence of demographic factors.

- Intuition: the more concentrated the demographic structure on cohorts with a high saving rate, the higher the effect on capital supply of recycling a carbon tax through lower proportional taxes on income, the higher the positive influence on long-run GDP of the second dividend.

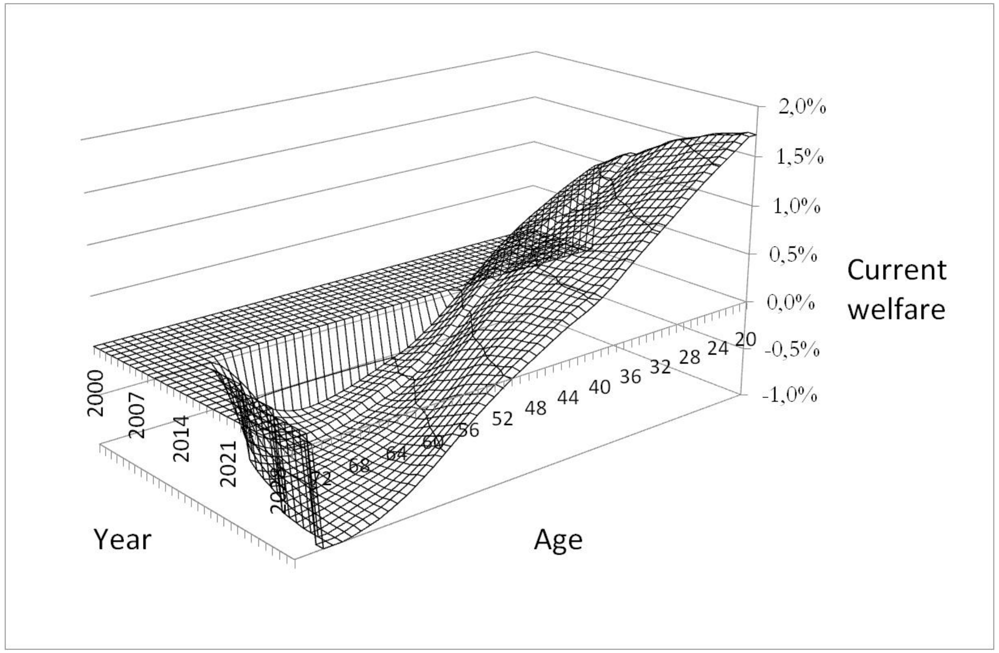
- For a carbon tax of around 1% of GDP that is fully recycled, positive effect between +0,1% and +0,5% of GDP in the long run, depending on whether the recycling concentrates on working population or not.



APPLICATION 1: THE SECOND DIVIDEND AND THE DEMOGRAPHIC STRUCTURE (4/5)

The 2nd dividend has pro-youth intergenerational redistributive properties. Joint influence of a distortive effect and a capital deepening effect:

- The former *bolsters* relatively more the wellbeing of the young cohorts.
- The latter *weighs* relatively more on the wellbeing of the aged working cohorts (through a lower yield for savings)
- This holds qualitatively whether the recycling of the carbon tax concentrates on the working population or not (i.e., recycled for the whole population).

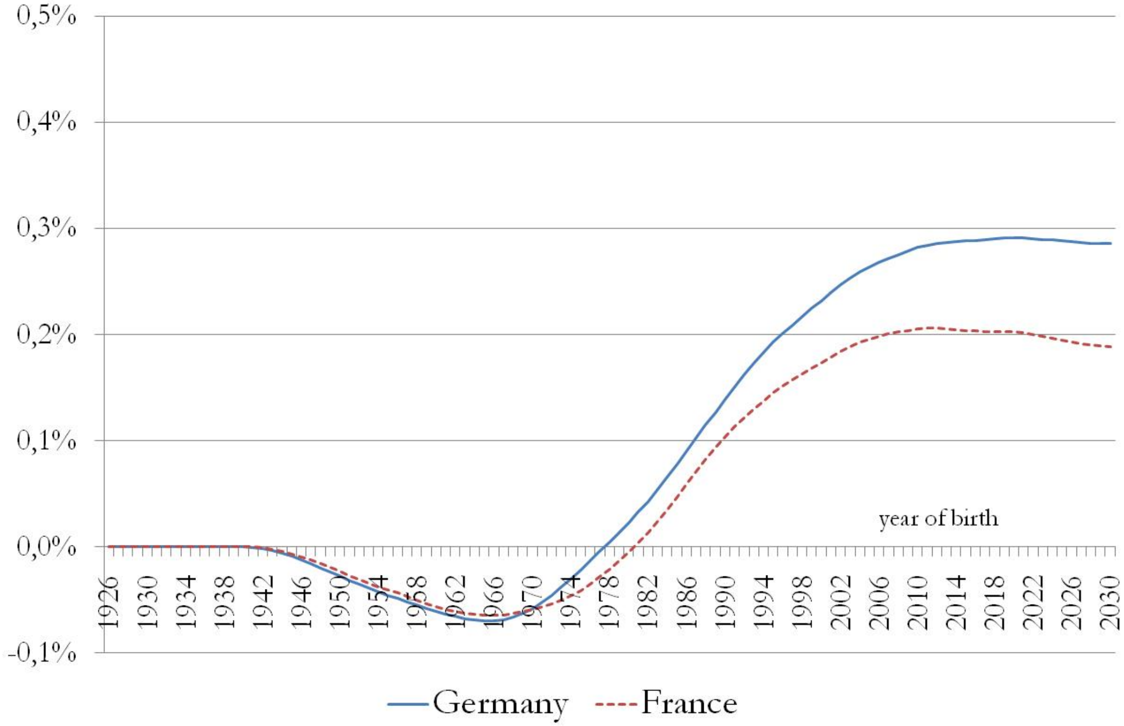


APPLICATION 1: THE SECOND DIVIDEND AND THE DEMOGRAPHIC STRUCTURE (5/5)

The magnitude of the intergenerational pro-youth property of the second dividend is influenced by demographics.

It is higher in a relatively older country than in a younger one.

(graph shows intertemporal welfare for each cohort depending on its birth year)



APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (1/8)

Policy scenarios:

- **Scenario A** is the baseline, **no-reform** scenario. No centrally implemented rise in public targets for renewables in the mix, no carbon tax in the future.
- **Scenario B** adds to scenario A a centrally implemented rise in the fraction of **renewables** in the energy mix (financed by a specific feed-in tariff).

  … so that it achieves a reduction in carbon emissions of x% in 2050 as compared to 2009 (i.e., the year preceding the public announcement of the reform in 2010).
- **Scenario C** adds to scenario A one **recycled carbon tax** created in 2015 and increasing by 5% in real terms per year afterwards.

  … so that it achieves a reduction in carbon emissions of x% in 2050 as compared to 2009.

  The income associated with the carbon tax is recycled through lower proportional taxes on households' gross income.

  No centralised policy in favour of renewables in scenario C.

APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (2/8)

Higher quantitative targets set by public authorities for the future development of renewables…

- … weigh on growth in the long run in the model. Intuition: it fosters energy prices for private agents, forcing them to buy at a higher price (at least in the short-medium run) a good necessary for production with no perfect substitute.

  While lessening the demand for energy in the model, the rise of renewables in the mix triggers some capital deepening: higher energy prices weigh on disposable income: life-cycle behavior imply a rise in the saving rate, with an upward effect on the supply of K.

- … weigh on the intertemporal (material) welfare of all cohorts - however, the detrimental effect is less pronounced for currently older generations.

  Permanent income effect: the younger a cohort today, the longer it will bear the cost of increasing energy prices associated with more renewables in the mix, ceteris paribus. And vice-versa.

APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (3/8)

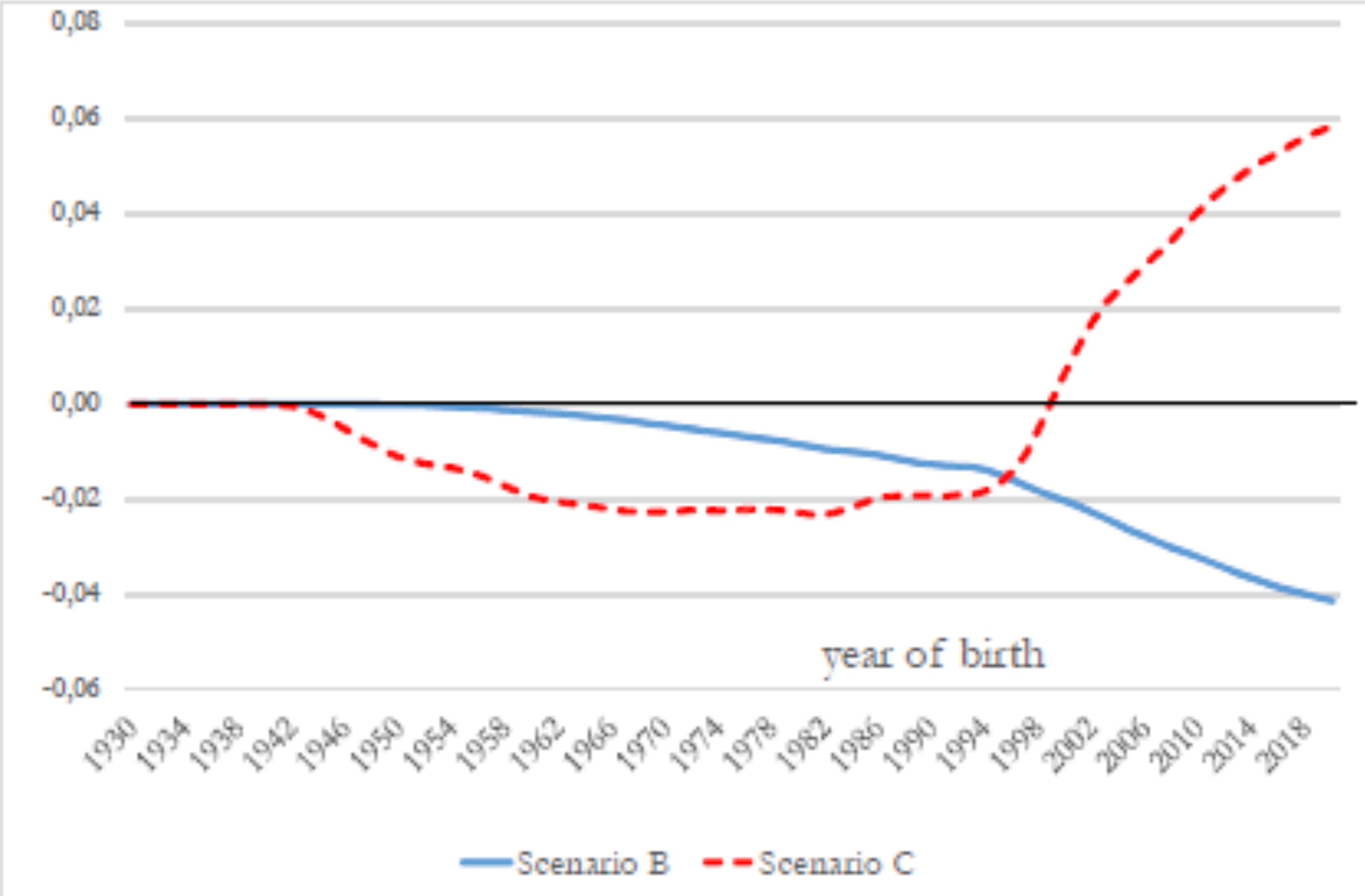
A carbon tax (fully recycled through lower taxes on income) displays pro-youth intergenerational effects and is more detrimental to currently relatively aged working cohorts and current retirees.

- *Recycling a carbon tax through a lower proportional tax on income amounts, in absolute terms, to distributing relatively more revenues to cohorts receiving higher income (i.e., currently aged and working cohorts, more productive).*
- *The net effect of the recycled carbon tax is positive for the* current *income of aged working cohorts at any year in the model, but negative for the* current *income of young and retired cohorts.*
- *The influence on the* permanent *income of a recycled carbon tax is negative for the cohorts which are retired or aged but still active when the tax is implemented, and positive for the permanent income of future generations.*

The influence on the intertemporal welfare of currently young active cohorts stems from the joint effects of a rising rate of the fully recycled tax, its associated downward effect on the rate of the proportional income tax, its influence on income depending on the age of the cohort, and the interrelations of all these influences in the general equilibrium.

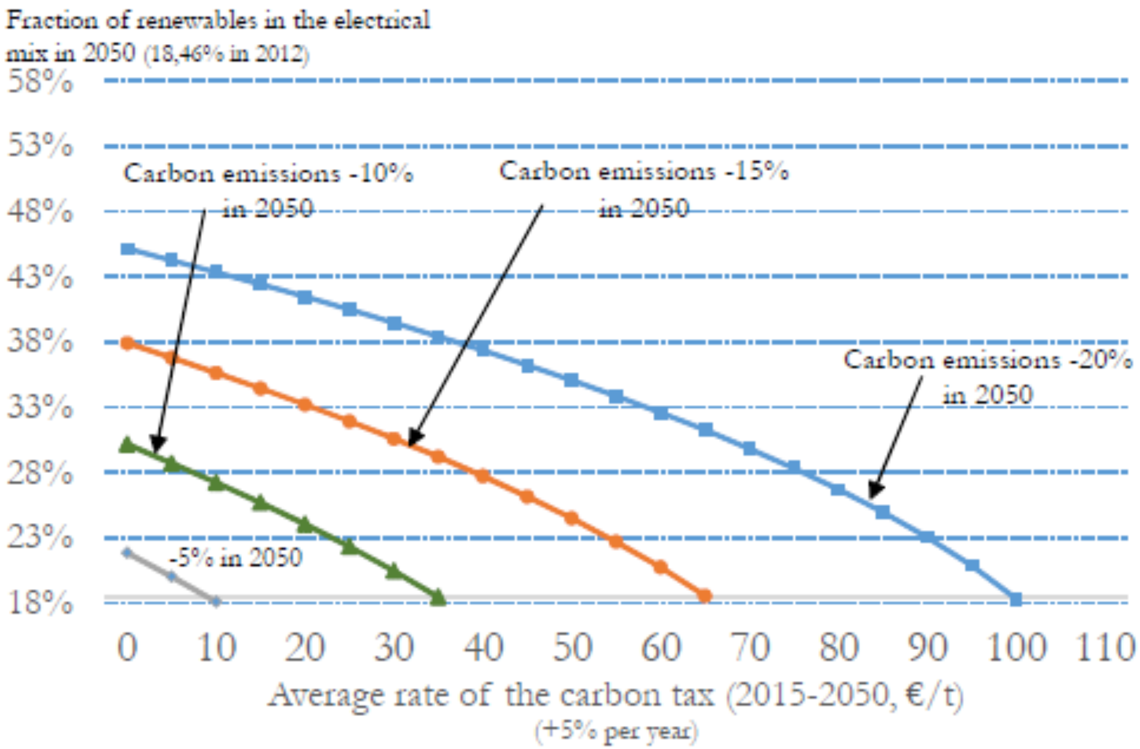
APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (4/8)

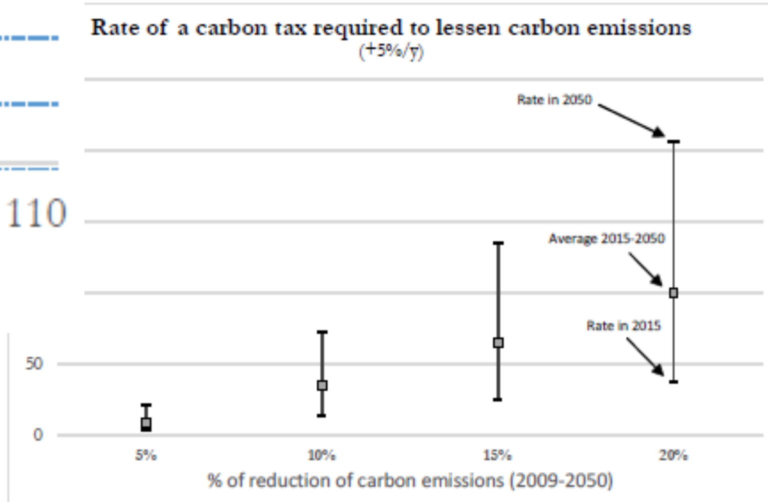
FOR THE SAME LEVEL OF CO2 EMISSIONS



APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (5/8)

Curves of iso-reduction of carbon emissions in the model





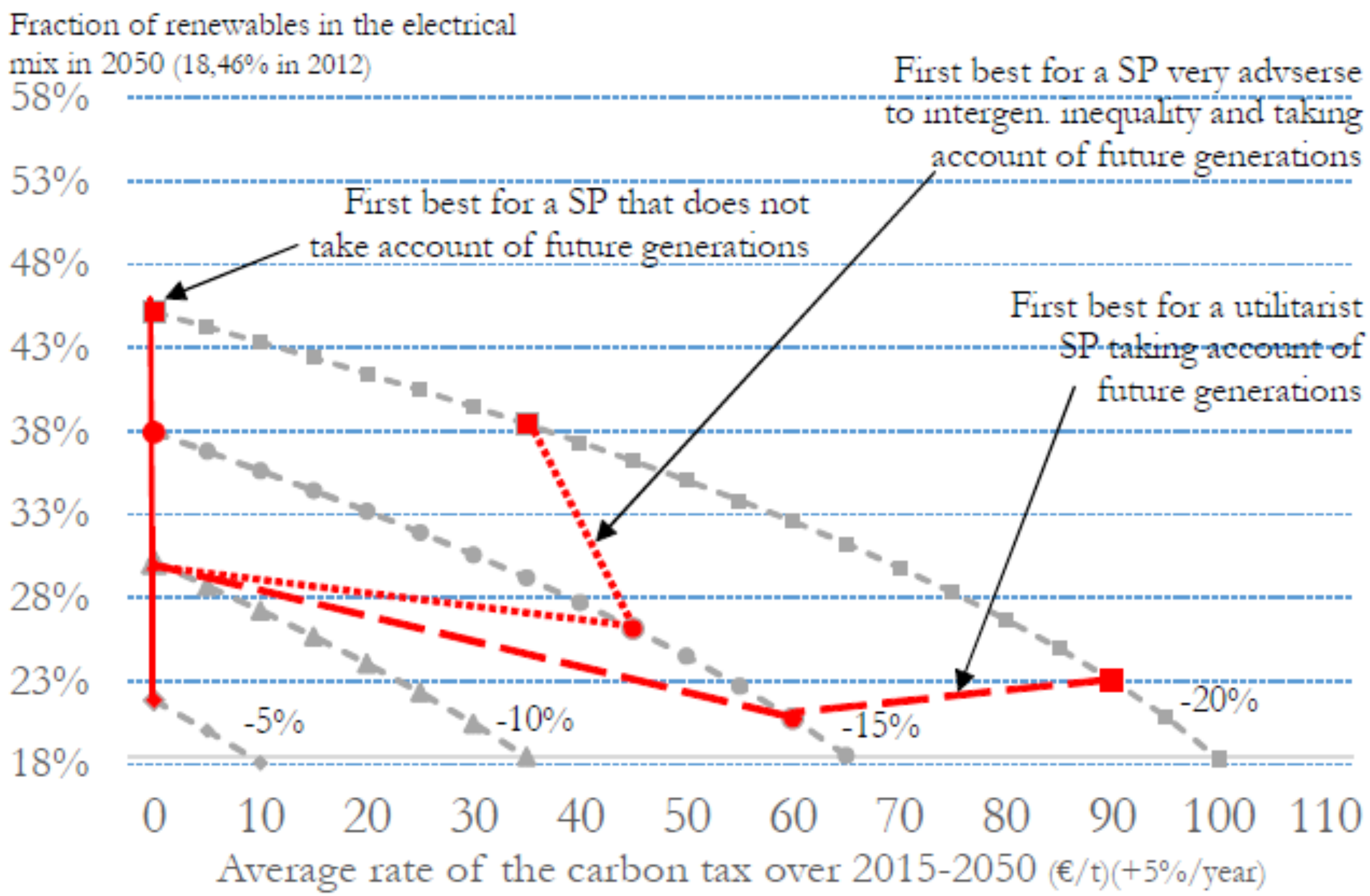
APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (6/8)

Different types of social preferences used in the model

	Social aversion to intergenerational inequality	
	None	High
Social planner takes account of the welfare of future generations	A	B
Social planner does not take account of the welfare of future generations	C	D

APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (7/8)

Optimal mix of instruments for a social planner aiming to lessen carbon emissions, depending on its social preferences



APPLICATION 2: FOSTERING RENEWABLES *VS* RECYCLING A CARBON TAX (8/8)

While a carbon tax triggers better effects on growth than developing renewables for a given target of reduction of CO2 emissions, it does not necessarily maximise the social welfare because it raises about intergenerational redistributive effects:

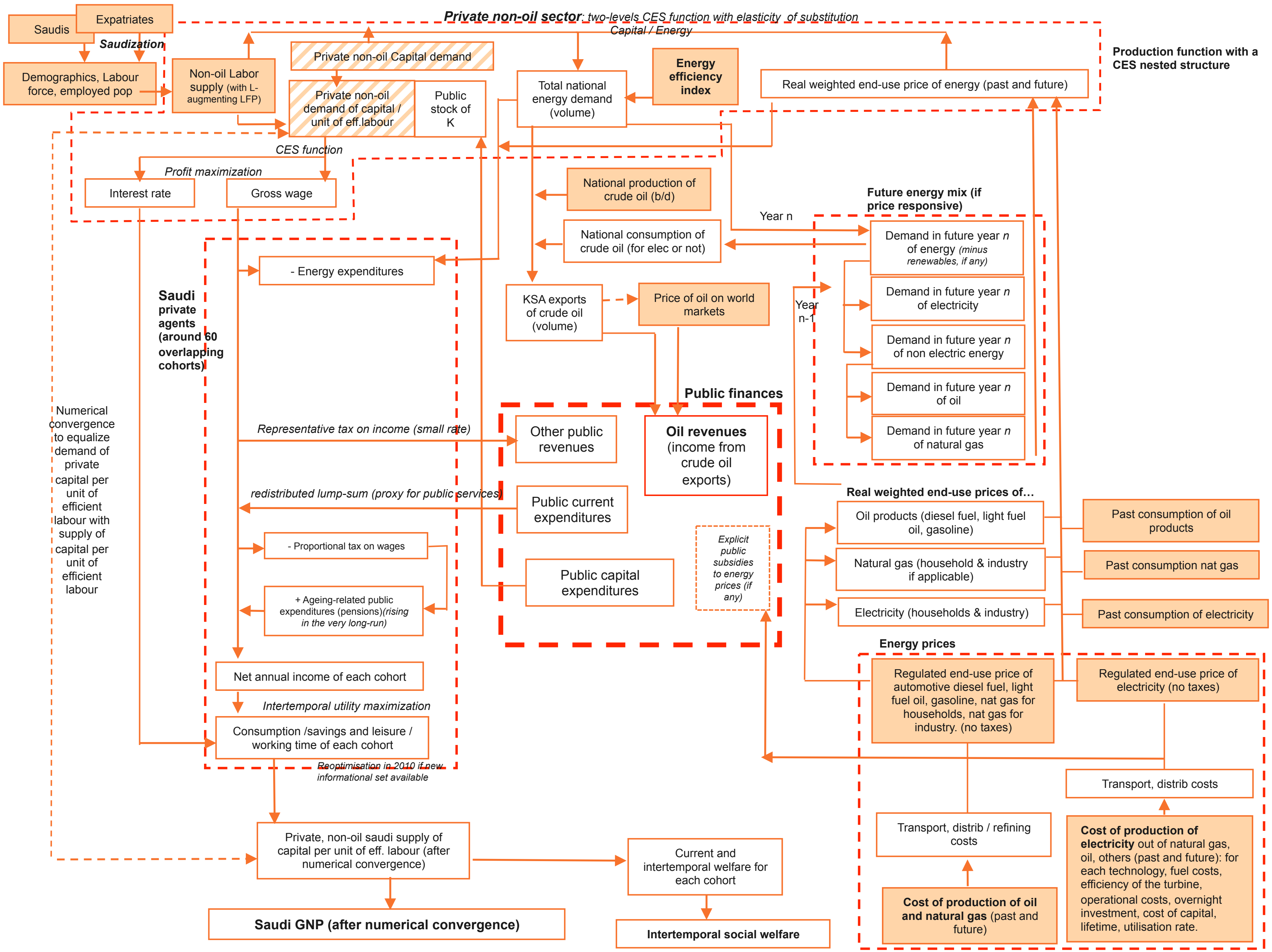
- The policy chosen depends from social preferences as concerns intergenerational inequality and the wellbeing of future generations.
- Governments can decide to implement regulations increasing the fraction of renewables in the energy mix along with the creation of a fully recycled carbon tax.

Incidentally, our model also suggests that a mix of a carbon tax and a centralized policy favoring renewables may not be enough to meet targets of carbon emissions diminution as high as 70%/80% in 2050, as often advocated for in the public debate (this is in line with Henriet, Maggiar and Schubert, 2014).

APPLICATION 3: EFFECTS OF ENERGY POLICIES IN OIL-EXPORTING COUNTRIES (THE *SAXUM* MODEL) (1/4)

- Designed for oil producing countries (here, Saudi Arabia/GCC) which…
  - have relatively low energy efficiency
  - implement regulated/subsidized prices of energy
  - benefit from massive public incomes from oil exports
  - have rapidly growing native populations
  - have a high proportion of expatriates
  - have low taxes
  - need more public investments so as to foster economic development.

- New, adapted structure of the model (see next slide)



Saudis
Expatriates
Saudization
Demographics, Labour force, employed pop
Non-oil Labor supply (with L-augmenting LFP)
Private non-oil Capital demand
Private non-oil demand of capital / unit of eff.labour
Public stock of K
Private non-oil sector: two-levels CES function with elasticity of substitution Capital / Energy
Total national energy demand (volume)
Energy efficiency index
Real weighted end-use price of energy (past and future)
Production function with a CES nested structure
CES function
Profit maximization
Interest rate
Gross wage
National production of crude oil (b/d)
National consumption of crude oil (for elec or not)
Future energy mix (if price responsive)
Year n
Demand in future year n of energy (minus renewables, if any)
Demand in future year n of electricity
Demand in future year n of non electric energy
Demand in future year n of oil
Demand in future year n of natural gas
Year n-1
- Energy expenditures
Saudi private agents (around 60 overlapping cohorts)
KSA exports of crude oil (volume)
Price of oil on world markets
Public finances
Other public revenues
Oil revenues (income from crude oil exports)
Representative tax on income (small rate)
redistributed lump-sum (proxy for public services)
Public current expenditures
Public capital expenditures
Explicit public subsidies to energy prices (if any)
Numerical convergence to equalize demand of private capital per unit of efficient labour with supply of capital per unit of efficient labour
- Proportional tax on wages
+ Ageing-related public expenditures (pensions)(rising in the very long-run)
Net annual income of each cohort
Intertemporal utility maximization
Consumption /savings and leisure / working time of each cohort
Reoptimisation in 2010 if new informational set available
Real weighted end-use prices of...
Oil products (diesel fuel, light fuel oil, gasoline)
Natural gas (household & industry if applicable)
Electricity (households & industry)
Past consumption of oil products
Past consumption nat gas
Past consumption of electricity
Energy prices
Regulated end-use price of automotive diesel fuel, light fuel oil, gasoline, nat gas for households, nat gas for industry. (no taxes)
Regulated end-use price of electricity (no taxes)
Transport, distrib costs
Transport, distrib / refining costs
Cost of production of oil and natural gas (past and future)
Cost of production of electricity out of natural gas, oil, others (past and future): for each technology, fuel costs, efficiency of the turbine, operational costs, overnight investment, cost of capital, lifetime, utilisation rate.
Private, non-oil saudi supply of capital per unit of eff. labour (after numerical convergence)
Current and intertemporal welfare for each cohort
Saudi GNP (after numerical convergence)
Intertemporal social welfare

APPLICATION 3: EFFECTS OF ENERGY POLICIES IN OIL-EXPORTING COUNTRIES (THE *SAXUM* MODEL) (3/4)

- Higher energy efficiency acts on aggregate energy productivity through two main channels in GCC countries:
  - a direct impact of energy efficiency results (lower energy consumption for a given level of output + higher levels of activity and greater energy consumption (rebound effect).
  - impact on the fiscal balance of Saudi Arabia due to increased oil revenue from selling otherwise domestically consumed oil onto the export market.
- Two alternative scenarios are considered as concerns the way revenue from additional oil exports is used:
  - Scenario B: using the EE fiscal dividend to reinvest into expanding the public capital stock (-> infrastructures).
  - Scenario C: using the EE fiscal dividend to reinvest into expanding current (non-capital) public spending.

APPLICATION 3: EFFECTS OF ENERGY POLICIES IN OIL-EXPORTING COUNTRIES (THE *SAXUM* MODEL) (4/4)

(work in progress in november 2015)

Future EE gains of +4%/y up to 2050 (instead of 0% as in the past) could foster Saudi GNP by +0,3%/+0,5% per year over next 5 decades:

- Recycling EE gains through public transfers could trigger a sizeable impact on growth (+0,5% per year on average up to 2050) but with some significant drawbacks: effect vanishes as soon as EE gains disappear + private agents' income depends increasingly from public finances and thus on oil income -- increasing concern for the macroeconomic stability of KSA.
- Recycling EE gains through a rise in the stock of public K would have a positive macroeconomic effects, building up progressively (+0,3% per year on average up to 2050, still more afterwards) but with some significant advantages: the positive influence remains as long as infrastructures are used and thus keeps materializing even if energy efficiency gains disappear + income of private agents does not depend strongly on public transfers and oil income, strengthening the macroeconomic stability + policy more favorable to future generations who might face a deteriorated economic context.

CONCLUSION

- Intergenerational redistributive effects and demographic structures can play a significant role in energy & environmental economics and policies.

- OLG frameworks enshrined in EG modeling are well adapted for studying such issues.

See also Gonand F. (2015), “Ageing, the carbon tax and pension deficits”, *Environmental & Modeling Assessment*, forthcoming.

THANKS FOR YOUR ATTENTION

FREDERIC.GONAND@DAUPHINE.FR