Climate change, innovation and growth: perspectives from Europe

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Mean Surface-Ocean Temperature and CO2 Emissions

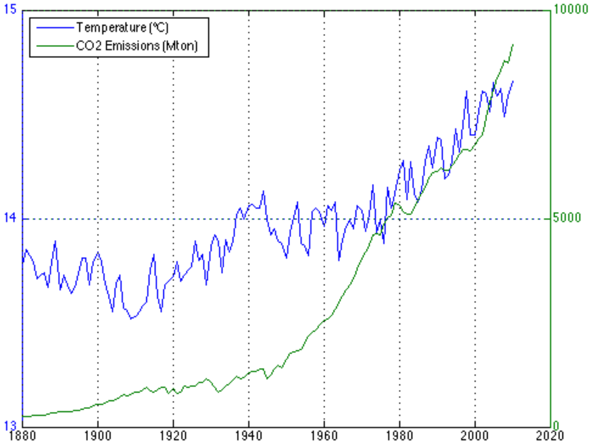
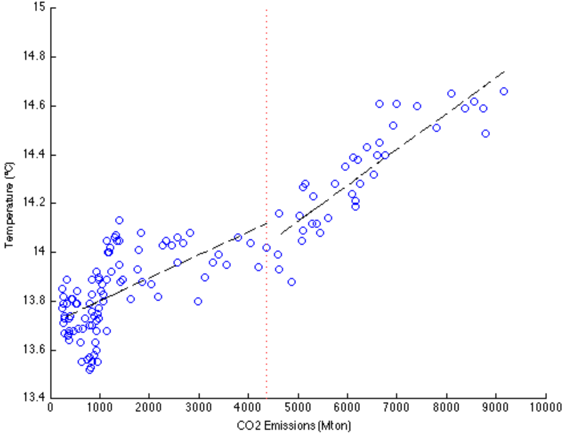


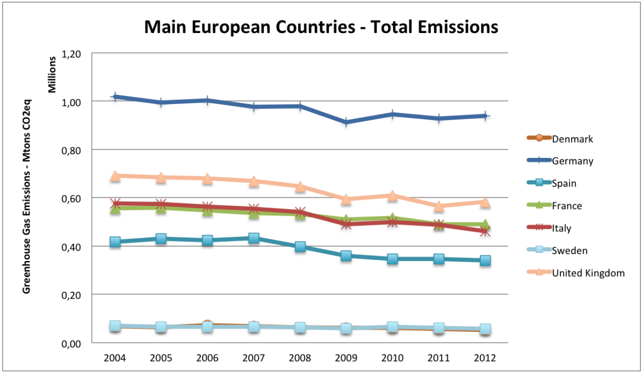
Figure : Temperature and CO_2 emissions dynamics: 1880-2013

Temperature vs. Emissions



- Break maximizing RSS before and after the break point: 4376 Mt C
- Two trends, increasing slope, $\frac{\beta_{post}}{\beta_{bef}} = 1.5649$

Europe and Emissions - is it enough?



average (yearly) growth 2004-2012			
EU28	-1.70%	France	-1.59%
Germany	-1.02%	Italy	-2.76%
Spain	-2.50%	UK	-2.12%

Europe and 2020 targets

- Share of renewable energy: 20% at EU level
  - projecting it up to 2020 using 04-11 average growth rates
  - only three countries do not meet the target (NDL, LUX, FRA)
  - UK, Italy and Belgium amongst the those with largest growth

- Emission cut of 20% with respect to 1990 at EU level
  - projecting it up to 2020 using 04-11 average growth rates
  - again, only three countries do not meet the target (MAL, LUX, DEU)
  - Finland, Denmark and Belgium those with the largest cutting rate

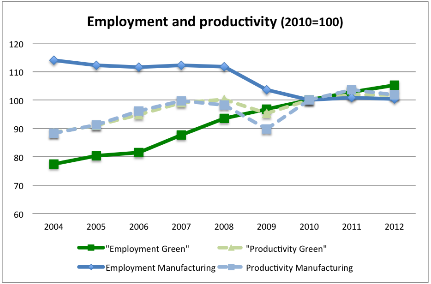
- (binding) Targets are likely to be met
- In many cases, they are likely to be met well before 2020

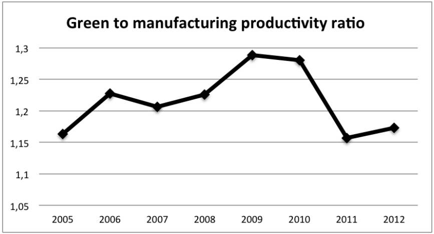
Europe and the Green Sector - a Sketch from last decade

- **Good news**
  - Employment in the green sector is increasing
  - Productivity of green sector higher than the rest of the economy
  - "Climate and Green" innovations are increasing
  - "Climate and Green" innovations are virtuous
  - Emissions and renewable energy share targets are likely to be met

- **Bad news**
  - Spending in environment protection is stagnant or decreasing
  - Private sector spending is much lower than public one
  - Relative productivity of the green sector has decreased with the Great Recession

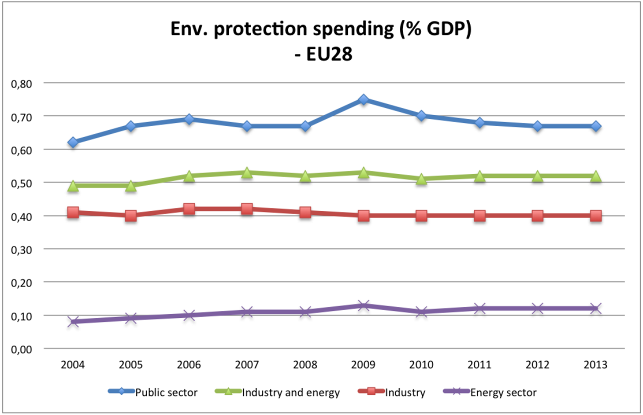
Employment and Productivity in the Green sector





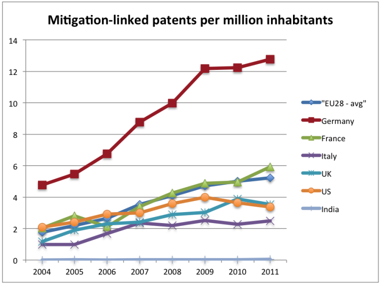
Spending in Environmental Protection

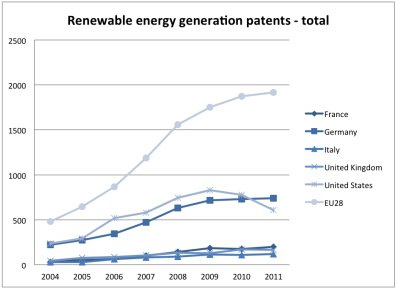
Environmental protection: all activities directly aimed at the prevention, reduction and elimination of pollution or nuisances to the environment.



Climate and Green Innovations

- Climate related innovations are increasing over time





Climate and Green Innovations

- Positive effect on employment and growth
  - both environmental and generic product innovation stimulate employment growth
  - not clear, which has the larger effect
    - environmental innovation relatively more important in services, non-environmental innovation relatively more important in manufacturing [Licht and Peters (2013) - 16 European countries]
    - focusing on Italian manufacturing, environmental innovations display a larger effect [Miriello et al. 2014]
  - eco-innovators grow more than general innovators
  - green gazelles grow more than gazelles [Colombelli et al. 2015]

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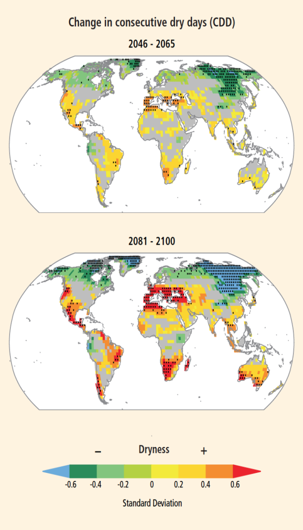
Climate Projections



- Climate extremes and extreme events
  - IPCC (2012): there is evidence of change in different extremes and that some have changed due to anthropogenic influences
  - IPCC (2012): there is high confidence that economic losses from climate/weather events have increased and with large interannual variability
- High-end scenarios
  - are those that describe climate change levels at the upper end of the range of possible futures
  - +3C, +4C

Green paradigm, climate paradigm? opportunity not to be missed

- Unbounded climate warming is likely to unprecedently affect the economic system and the society as a whole
- Economic and technological development materializes along trajectories embedded within paradigms [Dosi 1982, 1988]
- Paradigm shifts and technological revolutions have guided the long run process of growth and structural change [Perez 2002, 2009]
- Can the current Great Recession and the need to re-fuel the dynamics of growth be an opportunity?
  - Shifting production toward a new paradigm
  - "Green" might not be enough, climate change mitigation & adaptation
  - The role of the public spending is fundamental [Mazzuccato 2013]
  - A complex set of policy might be required [e.g. Nesta et al. 14]

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Models of the Economy with Climate Change

- Standard models with a climate side are inadequate [Pindyck 2013]
  - DICE [Nordhaus 92, 94, 08], FUND [Tol 02], PAGE [Hope 06]
  - Stern Review [Stern 07]

- Adaptation (of individuals, organizations, industries) requires to model heterogeneity

- The propagation of (climate) shocks on the production system requires a network perspective

- The uncertainty on the relationship between economic and climate variables requires to account for possibly non-linear dynamics

A possible gap in the modelling literature?

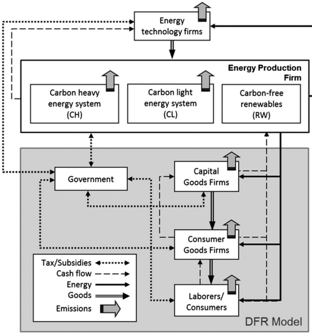
- emergence of ABM/complex systems approaches [Kelly et al 13, Balbi and Giupponi 09, Moss 02]...However:

- little effort in the development of integrate frameworks where the economy and the climate evolve endogenously through continuous *within* and *between* interactions

DSK - A Dystopic Schumpeter meeting Keynes model

- A laboratory for coupled **climate/macroeconomic policy** analysis
- Macro oriented ABM with endogenous technical change
- Energy, Financial, Consumption Good, Capital Good, Public sectors
- Climate Box with feedback loops and non-linear dynamics
- Stochastic Damage Generating Function

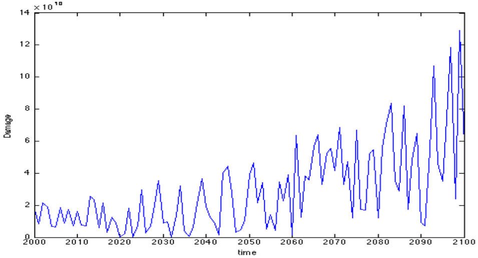
The basic architecture

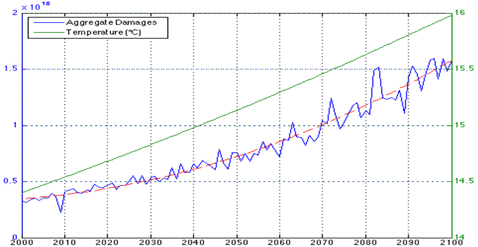


It allows to study, in conjunction

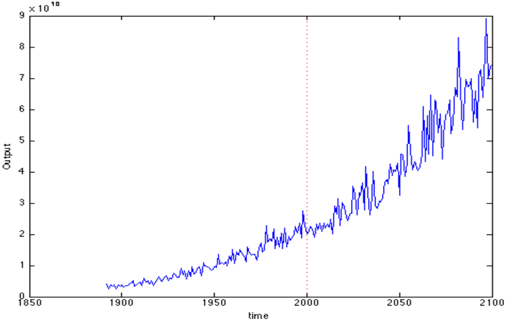
- industrial & innovation policies
- macroeconomic policies (e.g. fiscal)
- unconventional monetary policy (e.g Green QE, Green Bonds)
- mitigation policies (carbon tax, command and control)

Preliminary Results - Disasters, Shocks and Damages



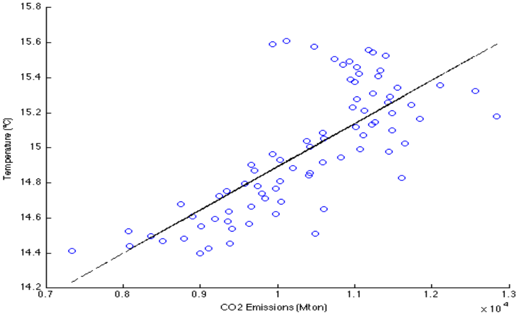


Preliminary Results - Output: Historical Training and Projections



- 1892-2000 [historical data]
  - climate box runs with historical data
  - and feed the disaster generating function
- 2000-2100 [simulation]
  - model runs and records output and shocks
  - average ratio of dirty/clean plant usage: 0.8

Preliminary Results: Emissions & Temperature



- Positive Relationship - in line with historical evidence
- Trend is increasing again: $\frac{\beta_{sim}}{\beta_{post}} = 1.4932$

Conclusions

- Europe is moving toward a greener economy
- Binding EU2020 targets seem not so strict
- Climate projections finds it at risk of extreme events (in addition to warming)

- A shift towards a new technological paradigm is needed and require a complex set of policies (and models adequate to explore them)
- Accounting for increasing variability in damages and hitting the economy with heterogeneous shocks
  - we obtain projections of large, non desirable, volatile growth
  - even though some shift towards green energies is in place

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Details - Capital and Consumption Good Sectors

- Machines (and production techniques) are characterized by 3 elements
  - Labour productivity (L), Energy Efficiency (EE), Environmental Friendliness (EF)
  - Technical change occurs along all the three dimensions
- Innovation and Imitation as two step procedure (within Capital Good sector)
  - 1_{st} phase [access]: draw from a Bernoulli(θ) where $\theta \propto$ R&D
  - 2_{nd} phase [size]: $A^k_{\tau+1} = A^k_{\tau}(1 + \chi^k_{A,i})$ with $k \in \{L, EE, EF\}$
- Unitary costs of production reflect the use of labour, energy and (eventually) carbon taxes
  - $c_i(t) = \frac{w(t)}{A^L_{i,\tau}} + \frac{c^{en}(t)}{A^{EE}_{i,\tau}} + t_{CO2} Em_i$
- In turn this affects investment decisions, which are made on the basis of a payback rule
  - if $\frac{p^{new}}{\left[\frac{w(t)}{A^L_{i,\tau}} + \frac{c^{en}(t)}{A^{EE}_{i,\tau}}\right] - c^{new}_j} \leq b$ then machine of vintage τ is replaced

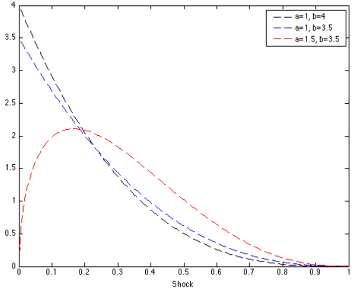
Details - The energy module

- A vertically integrated monopolist employing *green* and *dirty* plants
- Plants are heterogeneous in terms of cost structures, thermal efficiencies and environmental friendliness
- Unit production cost of energy
  - *green*: $c_{ge}(t) = 0$
  - *dirty*: $c_{de}(t) = \frac{p_f(t)}{A^{TE}_{de,\tau}}$ where $p_f(t)$ is the price of fossil fuels (exogenous)
- Total energy production cost depends on which plants are used
  - Plants are ranked on their unitary cost and are activated accordingly
- Price of energy is determined using a fixed-mark up rule
- Investments in the energy sectors are undertaken to expand production capacity
  - *green*: $IC_{ge,\tau} > 0$
  - *dirty*: $IC_{de,\tau} = 0$
- Innovations: either $\downarrow IC_{ge}$ or $\uparrow A^{TE}_{de,\tau}$ (up to the maximum of 1) and $\downarrow em_{de}$

Details - Modelling Damages and Disasters

- Pindyck (2013): the choice of the **damage function** is the most speculative element of the analysis
- Aggregating everything in a loss of final output it is missed the heterogeneity of possible damages and long run effects of disasters
- Impossibility of catastrophes

- we introduce a stochastic “disaster generating function”



Details - disaster generating function

Disaster Generating Function

A parametric probability density function for dis-aggregated shocks that endogenously evolve according to the dynamics of the climate

- $f(s; a, b) = \frac{1}{B(a,b)} s^{a-1}(1-s)^{b-1}$
- (location) $a = a(t) = a_0[1 + \log[T_m(t)]]$
- (scale) $b = b(t) = b_0 \frac{\sigma_{10y}(t-1)}{\sigma_{10y}(t)} + 1$
- (shock realization) $X_{i,} = X_i'[1 - \hat{s}_i(t)]$
- where X could refer to labour productivity, capital stock, number of workers, consumption level of agent i