Reducing the Fault Lines of the European Economy through the Low Carbon Transition

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Table of contents

Figures

Tables

Summary

The study analyses how the European Union can resist the temptation of postponing ambitious climate action after the end of the current economic uncertainty and social alarms that fuel self-isolation reflexes. It tries and demonstrates that not engaging ambitious climate policies now would deprive Europe of a lever for a new growth regime, socially and geographically inclusive.

This demonstration retrieves many well-known advocacy elements in favor of 'green growth' (negative cost options, deployment of carbon free innovation, or the double dividends of carbon taxes) and resets them within a new mental map of the economics of climate change that incorporates a surprising absentee of the prevailing mental map, finance. In this mental map new opportunities of co-dividend of climate policies can primarily be explored to fill the gap between the propensity to save and the propensity to invest which is one of the major fault lines of the current economic growth engine.

A set of numerical simulations based on a general equilibrium model for 2nd best economies shows why Europe, starting from a stagnation scenario 'à la japonaise', cannot recover a high and sustainable growth trajectory even by mobilizing optimistic technological assumptions about low carbon options, a redirection of transportation investments and climate friendly fiscal reforms. These simulations demonstrate that the main deadlock comes from the technical and behavioral inertia that slow down the deployment of the benefits of such measures.

It then shows how this deadlock can be overcome by financial instruments apt to reduce the risk weighted capital cost of low carbon investments and to indicate where the savings should go instead of seeking refuge in liquid financial products or real estates. It concludes suggesting some avenues for reframing the European climate policies and their alignment with overall policies aiming at calming down internal tensions in Europe and at fostering a new growth regime.

Introduction

The European Union seems caught in a double bind. It pretends to exert a leadership in climate policies after the Paris Agreement while it faces internal distrusts about its capacity to secure well-paid jobs, to sustain a reasonable level of social security and to address the 'immigration' challenge. Together with increasing divisive lines between former Western and Eastern Europe, Brexit is one symptom of a temptation of self-isolation that is not conducive to ambitious climate policies.

This double bind might last in a context where the recent recovery from the 2008 crisis might be fragilized by the continuing exacerbation of inequalities (World Bank 2016; Dablas-Norris et al. 2015), by diverging trends in the economies of the European countries (Aglietta 2014) and by the risks of 'secular stagnation' pinpointed by prominent economists (Lewis et al. 2014; Blanchard et al. 2016).

One logical temptation is then to postpone ambitious climate action after the end of the current economic uncertainty and social alarms. Given the pace at which the available budget of carbon emissions shrinks to meet the 2°C target (UNEP 2017), this comes to a 'climate resigned attitude' that admits the scientific alerts, contrary to the 'climate sceptic attitude', but considers *de facto* that the battle is lost. This study turns the question upside down. It argues that, whatever the judgment about at what level we will ultimately stabilize global warming, not engaging the climate fight now would deprive Europe of a lever to launch a new growth regime, socially and geographically inclusive and to shape the future of the economic globalization process.

This demonstration will inevitably retrieve many well-known advocacy elements in favor of 'green growth' even though these elements (negative cost options, deployment of carbon free innovation, or the double dividends of carbon taxes) often fail to convince 'climate resigned' and generate a *'too good to be true'* intellectual reflex. It will reset them within a new mental map of the economics of climate change that incorporates a surprising absentee of the prevailing mental map, finance, which is both one driving force of the modern world economy and a key policy domain.

The dominant economic framing of climate policies pictures indeed a world where sectors or countries are 'emissions abatement factories' using an evolving mix of existing and future technologies. In this world, the optimal response is a 'where and when' flexibility: to abate emissions at each point in time where it is cheaper to do so and follow an abatement trajectory that does not impose premature costs on current generations that could be avoided by abating more later thanks to cheaper new techniques.

However, for reasons of macroeconomic efficiency and of social acceptability, the pace at which carbon prices can increase in every country depends upon the pace at which government will be able to insert them in reforms of the fiscal system and of the public policies. This pace will likely be too slow to meet the 2°C target. In the dominant economic mental map described above, a unique carbon price throughout the world comes to bypass this constraint. However, it will maximize global welfare only if large transfers across countries are operated to compensate for its adverse distributive effects[1]. In addition to exacerbating the self-isolation political reflexes, this option confronts a double difficulty, assessing these transfers given the magnitude of the general equilibrium effects of significant carbon prices and securing that they will not generate pure windfall benefits (Waisman et al. 2013).

A solution space can be found to align climate policies with short term economic policies and long-term development policies only if climate policies can help economies to function closer to their full potential and can generate a carbon saving technical change without loss in overall productivity. Historically, proposals in this direction focused on reducing the energy efficiency gap, conducting climate friendly fiscal reforms or reducing subsidies to fossil fuel consumption. However, the double-dividend to be expected from these policy parameters is limited by the vested interests they threaten and the distributional issues they raise. Although they remain valid, new opportunities of co-dividend of climate policies have to be explored that were neglected so far and they have to be searched within some of the major fault lines of the current economic growth engine. One is the low development of domestic infrastructures (IMF 2013) often generated by the *'export to grow'* imperative of the current globalization pattern (Rajan 2010); another one is the gap between the propensity to save and the propensity to invest (Summers 2015; Blanchard 2016). This study will consider only indirectly the former and place the focus on the latter.

This gap relates indeed basically to the increase of the risk component of decisions despite the low level of interest rates of central banks: small and medium enterprises with a difficult access to finance, large corporates under a 'shareholder business regimes', households concerned by the weakness of the social safety net. This creates a Buridan Donkey syndrome where the cash holder does not know where to invest productively[2].

Climate finance can then come into play to break this syndrome by indicating where the 'cash' should go instead of seeking refuge in liquid financial products or real estates. The introduction of climate finance does not disqualify old debates about the respective role of prices and regulation in the redirection of technical change or about the use of carbon revenues to minimize the social cost of climate policies or even to turn them into a gain. But it changes substantially the terms of this

[1] That is why article 136 of the Paris Agreement that carbon pricing *"applies to non-party entities, and is not binding upon countries that are parties to the UNFCCC."*

[2] The Buridan Donkey is an old legend where, in front of a bucket of water and a pile of oat, the donkey educated in a too rationalistic way dies because it hesitates too much between drinking first and eating first

debate, including because it helps overcome some of the short-term barriers to climate policies, thanks to luring the risk waited capital cost of low-carbon investments of which importance is convincingly highlighted by Hirth and Steckel (1997). To avoid presenting mistakenly climate finance as a novel magic bullet in the same way as carbon taxes or R&D funding have been often presented in the past, we will we proceed in three steps.

First, a description of the IMACLIM-R model utilized in this report will be used to specify the many types of 'sub-optimalities' at play in a 'second best economy' and to define 'virtual' scenarios embarking increasingly rich 'policy packages', starting from pure command and control policies in the energy sector and adding successively infrastructure policies, tax reforms and financial devices. A second section will demonstrate how climate policies might generate a significant burden on an already fragile European Union. A third section will show how the interplays of policy instruments within the increasingly rich packages previously defined give levers to transform this burden into a gain and help Europe escape the risk of a stagnation phase 'à la japonaise' (IMF 2016).

1 Scenarios for economies below their production frontier

A dominant practice for assessing the economic implications of climate policies is to compare a reference and a policy scenario using a general equilibrium model that represents how economies situated on equilibrated growth pathway behave with or without carbon constraints, given information on technical potentials provided by production functions or various forms of coupling with engineering-based models. This approach is legitimate for picturing various long run equilibria. Its limits, for detecting how to align climate policies and overall macroeconomic and development policies is its failure in describing the transition from the current suboptimal state of the economy to the projected long-term growth pathways. As stated by the IPCC:

"Most models use a global least-cost approach to mitigation portfolios and with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century (IPCC AR4 WGIII SPM, Box 3)".

This is why the IMACLIM-R model used in this study comes back to the original General Equilibrium framework in the Johansen's sense (Johansen 1963, Chenery and Bowles 1971) where economic interdependencies are described without presuming the economy to be on a 'first-best' equilibrium[3] and located on its production frontier. The reader will find more detailed descriptions of the motives and technical characteristics of the IMACLIM-R world model in Sassi et al (2009), Waisman et al (2012b) and Bibas et al (2015). We summarize here its main features to understand how it captures some of the mechanisms needed for turning pessimistic predictions about the economic consequences of a low carbon transition into an optimistic vision of the capacity of this transition to help ending the current economic and political uncertainty.

1.1 Modeling second best economies

IMACLIM-R world is a hybrid recursive general equilibrium model that projects the world economy, split into 12 regions and 12 sectors, on an annual basis up to the end of the century. Europe is one of this region (EU 27 plus Macedonia, Norway and Switzerland).

[3] About the history of the misunderstandings due to the fusion between this tradition and the tradition of the applied general equilibrium models after Scarf, see Mitra-Kahn (2008).

1.1.1 A hybrid modelling framework

Like any general equilibrium model, IMACLIM-R represents the interactions between sectors and countries over time through the clearing of commodities markets. Its main difference is that this market clearing does not secure a full employment of installed production capacity and labor. This is due to dropping the perfect foresight assumption. A reluctance to drop this assumption comes from the *disadvantage of indefiniteness* (Solow 2000) given the many options available to represent expectations and from the tendency towards overshoot and collapse of *models with disequilibrium.* Confronted to the trade-off between '*definiteness and convenience'* (Solow 2000) most modellers prefer the definiteness of intertemporal optimisation: 'clairvoyance is an implausible assumption, but myopia seems even worse' (Manne-Rutherford 1994). The response of IMACLIM-R is to control the arbitrariness of behavioral assumptions and their technical realism. It incorporates in a consistent way, in a multi-sectoral growth model information coming from bottom-up engineering-based models and from experts' judgement about the behavioral specifics of sectors.

This information is obviously controversial but represents a hedge against the trap of combinatorial uncertainty. Indeed, IMACLIM-R is based on hybrid matrixes in money metric values and physical quantities[4] linked by a price vector that secures consistent description of the money and physical flows in an economy (Sands et al. 2005). This dual description guarantees that the projected economy is supported by a realistic technical background and, conversely, that any projected technical system corresponds to realistic economic flows and consistent sets of relative prices[5]. Explicit physical indicators allow a rigorous incorporation of sector-based information about how final demand and technical systems are transformed by economic incentives, especially for very large departures from the reference scenario.

This representation gives up the conventional KLE or KLEM production functions that, after Berndt and Wood (1975) and Jorgenson (1981), were admitted to mimic the set of technical constraints impinging on an economy. Regardless of questions about their empirical robustness[6], their limit is that, whatever their mathematical form, they are calibrated on cost-shares data through the Shepard's lemma which is a simple case of application of the envelope theorem. The domain within which this theorem provides a reliable approximation of technical sets is limited by (i) the assumption that economic values result from an optimal response of decision-makers to the price vector at each

[4] These are real physical indicators (mtep) passenger/kilometer, ton/kilometer, square meters or surrogated physical indicators for the energy intensive industries and composite goods.

[5] On the hybrid models see the special issue of the Energy Journal (Hourcade & Jaccard ed. 2006)

[6] After assessing one thousand econometric works on the capital-energy substitution, Frondel & Schmidt (2002) conclude that "inferences obtained from previous empirical analyses appear to be largely an artefact of cost shares and have little to do with statistical inference about technology relationship".

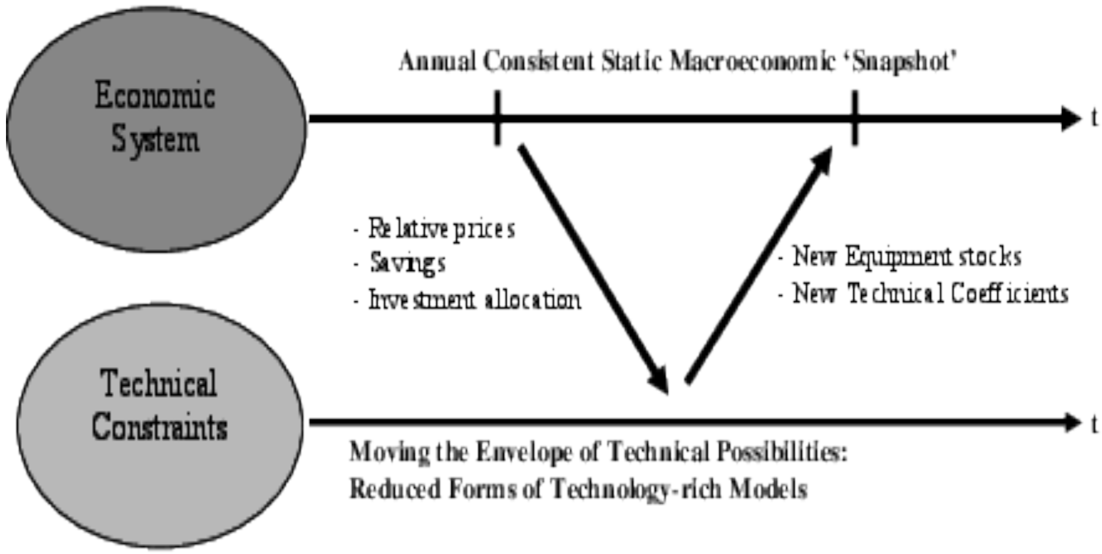
point in time given perfect foresight of the future prices trajectories and (ii) the lack of realism of constant substitution elasticities to describe the space of technical possibilities over short and long-term time horizons.

In the absence of mathematical functions suited to cover large departures from the reference equilibrium and flexible enough to encompass all the scenarios resulting from the interplay between consumption styles, technologies and localization patterns (Hourcade 1993), IMACLIM-R generates the production functions underpinning the economies at each point in time through a recursive exchange of information between:

- An annual static equilibrium in the strict meaning of accounting equilibrium not of optimal equilibrium: the production function is Leontief with fixed equipment stocks and intensity of labor, energy and other intermediary inputs, but where it is possible to adapt the utilization rate of production capacities. Solving this equilibrium at "t" provides a snapshot of the economy at this date: a set of information about relative prices, the structure of final demand, the share of this demand addressed to the domestic production sectors, the employment level and the profitability of each sector,

- Dynamic modules that combine trends of potential growth (demography and general factor productivity) and sectoral models that describe investments behaviors, the dynamics of capital stocks and the evolution of technologies (power generation, buildings, transportation infrastructures, energy efficiency). These modules take as inputs the economic values of the previous static equilibria, assess the reaction of technical systems and send this information back to the static module in the form of new input-output coefficients to calculate the t+1 equilibrium.

Fig. 1: An iterative dialogue « top-down / bottom-up »



1.1.2 A (sub-optimal) static equilibrium in physical and money flows

In the IMACLIM static equilibrium, domestic and international markets for all goods are cleared by a unique set of relative prices that depend on agents' behaviors on the demand and supply sides. The calculation of this equilibrium determines relative prices, wages, labor, quantities of goods and services, value flows. In each region, the demand for each good comes from household consumption, government consumption, investment and intermediate uses from other production sectors.

Consumers' final demand results from a utility maximization program of a representative consumer that has three distinctive features:

- Energy commodities are production factors of mobility and housing services and are not directly included in the utility function. This allows for making a clear distinction between energy efficiency and the evolution of consumption patterns in the decoupling between energy consumption and growth.
- The link between mobility services and energy demand encompasses the availability and efficiency of four transport modes: terrestrial public transport, air transport, private vehicles and non-motorized. Due to differences in amenities delivered by each mode and in specific local conditions, the transport modes are imperfect substitutes and IMACLIM-R nests them in a constant elasticity of substitution function.

- Households make decisions under two budget constraints: their income budget (the sum of wages, dividends and public transfers) and a 'travel-time budget'. This budget is justified by empirical findings (Zahavi and Talvitie 1980) showing the average daily travel time of households in a large panel of cities remains constant over decades. It allows for representing the rebound effects of the mobility demand in case of lower costs of vehicles with a higher energy efficiency.

In the static equilibrium, producers operate under short-run constraints of (i) fixed input-output coefficients and (ii) a fixed maximal production capacity, defined as the maximum level of physical output achievable with the installed capacity generated by previous choices.

Then the only margin of freedom of consumers and producers at a given point in time is to adjust the utilization rate of their equipment according to the prevailing market conditions which might differ from the expectations that guided the previous choices. This means that the consumption basket is not fully optimal and that the production factors are not always fully operated.

Overall demand can be provided by either domestic production or imports. For non-energy sectors, the model uses the conventional Armington specification (Armington 1969) which assumes that domestic and imported products are non-perfect substitutes. This allows for representing markets in which domestically produced goods keep a share of domestic markets even though their price is higher than the world price and various exporters co-exist on the same market even with different prices. While ensuring the closure of international markets in value terms, this specification does not allow for summing international trade flows in physical terms. This is not a drawback for "composite goods", where quantity units are not used in the analysis of the economy-energy-climate interface, but this is not compatible with the need of tracking energy balances in physical units. Therefore, for energy goods, the model uses a formula whereby the share of the domestic and imported goods is function of the domestic production prices relative to the international prices.

The most important closure rule for describing trade flows in the model is an exogenous assumption about the allowed trade deficit/surplus of trade balances or each country. The model assumes that the payment balance of every country is then equilibrated by capital exports/imports. This closure rule has a critical impact on the wage setting in each country: the higher the allowed trade deficit, the lower is the international competitiveness constraint on the country and the higher the wages.

1.1.3 Endogenous growth dynamics: between potential and real growth

The growth engine described in IMACLIM–R is fueled, like in any growth model, by investment dynamics given a production frontier. Contrary to a Solow type model, this possibility space is not given by a production function and an exogenous technical progress. It is given by the interplay between:

- The potential growth reachable at each point in time which is the product of the working-age population and of the overall labor productivity given technical constraints at the sectorial level that govern the productivity of energy and of other intermediate inputs. Overall labor productivity is function of a catch-up dynamics of the US labor productivity and this catch-up is function of cumulated investments though endogenous learning by doing processes. The change in technical constraints depends upon the cumulated investment of each of the technologies represented in sectorial models. Given explicit technical asymptotes (see Fig. 1) the cost of each technology decreases in function of the cumulated investment allocated to it.

- Decision – making under non-perfect foresight[7]. Investments are triggered in a sector when meeting the final demand addressed to this sector forces a too high utilization rate of installed capacities. Decreasing returns then enter into play with higher labor costs and intermediary consumption (Corrado and Mattey 1997). Under the constraints of technical inertia (the new capacities are a small share of total capacity) the model describes, in case of mis-expectation (of oil prices or of the final demand to a sector) adjustment costs which generate a gap between potential growth and real growth.

In a nutshell, the working of the growth engine in IMACLIM-R is governed by the quality of expectations and/or the stability of key economic parameters (the oil prices in this study). Its direction is governed by trends in development patterns (consumption, technology, spatial development) and by the capacity of policy signals to alter these patterns. Its rate is function of the level of investment decisions and of their quality, their capacity to remove technical constraints that could slow down a given development path (fossil fuel reserves for carbon intensive pathways, costs of alternative energies for low carbon pathways). This modelling structure can then capture how stabilizing the expectations through well designed climate policies can be a major lever to reduce some structural fault lines of our economies.

1.2 IMACLIM calibration: a backcasting exercise

The capacity of models describing non-equilibrated growth pathways to deliver useful information depends upon their capacity to reproduce, at least roughly, past ups and downs of the economies. This is why the calibration of IMACLIM–R was made through a back-casting exercise reproducing the

[7] In most cases, expectations for demand take into account demand growth in the past three years and prolong that trend. The expectations of demand encompass a fifteen years' period in the energy sectors. In the central case, most agents are assumed myopic for prices (i.e. current prices will apply in the future). When the carbon price is clearly announced by the government, the carbon price can be perfectly anticipated.

observed trends between 2001 and 2013. For the 2001 base year we modified the set of balanced social accounting matrices (SAM) of the world economy provided by the GTAP-6 data set (Dimaranan 2006) to make them fully compatible with 2001 IEA energy balances (in Mtoe) and data on passengers' mobility (in passenger-km) from Schafer and Victor (2000). In a second step, the dynamic equations were calibrated so that the calculated trajectory for economic growth and energy are not very far from past trends and from the 2013 data.

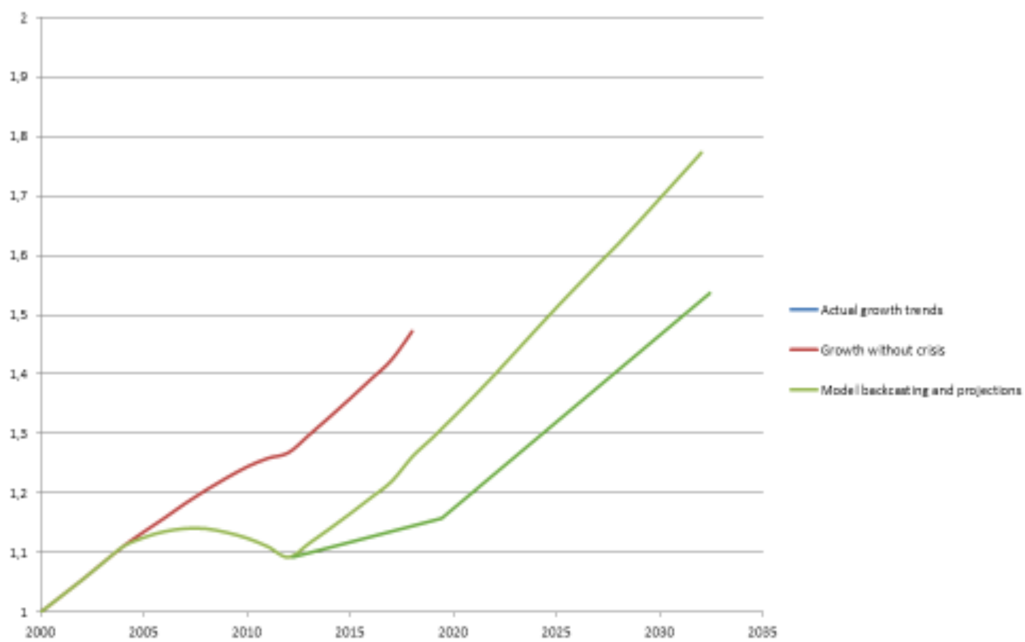
This exercise had to confront the existence of many shocks over this time period: the shock exchange rates between Euro and $, the real estate bubble in some countries, the 'oil shock', the financial crisis and the 'counter oil shock'[8]. We checked that it was possible to represent the gap between the calculated steady growth and real trends through a very few exogenous and controllable assumptions. This was possible because, most of the relations between the energy sector and growth being endogenized in IMACLIM-R, the degrees of freedom to calibrate the dynamic equations on the observed trends are limited. The arbitrariness in the selection of parameters is constrained by the fact that any assumption about one parameter impacts the others through the double constraint of consistency of flows both in value and prices at each point in time. An assumption can be thus rejected if it leads to attribute a non-plausible value to one of these parameters. The calibration process we carried out for the version of IMACLIM-R utilized in this report can be judged successful because:

- It was proved possible to fit the model to the real trends after the 'external shock' of the 2008 financial crisis by modifying only the 'catch up' trend in the potential productivity of labor. Although the IMACLIM growth engine does not endogenize the productivity effect of the financial cycles, this makes possible to build economic recovery scenarios on the basis of a simple assumption about the date of a full return to the pre-2008 productivity trends in the absence of new external shocks due to energy tensions.
- The model succeeded to reproduce endogenously trajectories of oil prices that are not far away from real trends. The model did not capture the 'apex of the peak' around the 100$/bl on average in 2008 but anticipated that this level was not sustainable and it 'predicted' a decline. It could even anticipate the low oil prices over the past four years in case of 'market flooding policy' by the OPEC (Waisman et al. 2012b) and can generate the return of an upward trend under assumption

[8] Symmetrically, the econometrically-based models oversell their capacity to capture real trends: *total-factor-productivity calculations requires not only that market prices can serve as a rough-and-ready approximation of marginal products, but that aggregation does not hopelessly distort these relationships […] over-interpretation is the endemic econometric vice'* (Solow 2008)). First there is no historical period, excepted the 50s and the 60s in the Western World, with decades of steady growth without on which it would be possible to capture stable economic relationships. Second there is no certainty that revealed relations will resist the impact of structural changes in the economies, including changes in their governance. The more the models are disaggregated the more important is this stability problem and a high level of aggregation is needed for econometrically models at cost of a weak representation of energy, transport and building sectors which are key for a low carbon transition.

of modification of the implicit strategic choices in the OPEC.

Fig. 2: GDP growth rates after the crisis without exogenous shocks (%)



- Third, the differences between the calculated final energy demand and real trends are not significant, meaning that apparent energy-price and energy-income elasticities approximate real behaviors at the global level. There are higher differences in the detail of the energy balances recalculated by IMACLIM-R and the IEA record. But they do not matter for the macroeconomic analysis conducted here below. Most of the differences are due to second order problems like the absence of energy from waste (for heating systems) in our model which does not change the overall economic dynamics.

1.3 A stagflation reference trend confronted to two oil prices trajectories

The post-2016 growth rates in the EU up to 2035 will depend upon both parameters out of direct control of the EU and of parameters alterable by policy decisions. Amongst the exogenous parameters, the most critical are the hypothesis about a possible secular stagnation (economic doldrums in the Western World, duration of the current economic slowdown in emerging economies), the US monetary policy, the risks of currency war and the future of oil prices.

In the following numerical exercises, all parameters other than oil prices are kept constant. By 2035, we calculate average growth rate of 2.3% which is the lower band of the World Bank scenarios.

This restriction of the analysis to a single world scenario allows for focusing on how the EU could transform the GHG emissions objectives into a lever to avoid a 'Japanese stagnation' profile. Before the crisis, the 'natural' labor productivity trend in the EU was supposed to catch up the US labor productivity level about 2040 and then follow a 1.7% per year growth rate historically observed in the advanced economies since the 19th century. To picture the current uncertain context we assume that, in the absence of policy choices, the European catch-up will take place in 2060 only. The issue is then to understand what articulation between climate policies and other public policies is apt to improve this growth engine by accelerating the catch-up process and narrowing the gap between the potential and real growth.

1.3.1 Oil prices: geologically and geopolitically constrained trajectories

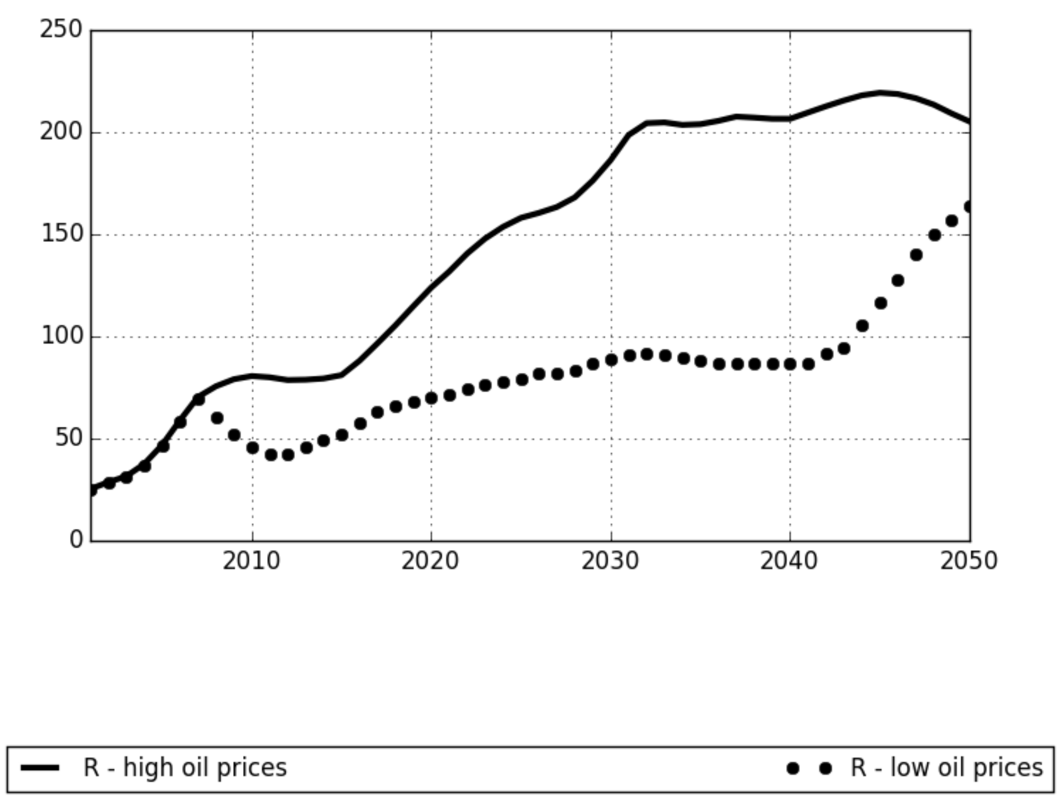
The decline of oil prices down to 35$/bbl last year is largely due a specific geopolitical context. It can be analyzed as an implicit oil market flooding strategy of the OPEC resulting from an economic trade-off, giving less weigh to the short-term losses in export revenues and more weigh to the long-term benefits of higher oil rents generated by the locking of oil importing economies in intensive development pathways (Waisman et al. 2012b). This strategic choice is consistent with a low public discount rate, capturing the capacity of governments to sustain long term strategies. However, as suggested by the recent increase of oil prices, both the necessity of increasing the revenues of the exportation of oil and gas revenues and the will of discouraging the oil importing country to raise carbon prices force not to stick to a univocal conjecture about the geopolitical context of the oil and gas markets. We thus retained two polar assumptions:

- A continued ***market flooding*** strategy aiming at a price of 40 $/bbl to discourage the deployment of alternative fossil fuel supply in the short run (including investments to export US shale oil and gas)
- A ***return to restrictions in oil supply*** to reap the short-term rents of oil markets through a price objective of 120$/bbl. This means lower investments and oil&gas supply and under exploitation of production capacities.

These strategies confront both geological constraints (the available reserves for given price levels and the 'Hubert curves' for the depletion of oil and gas fields) and technical constraints (the inertia in deploying both new oils and gas capacities and alternative technologies. The hybrid nature of IMACLIM-R allows for representing these geological constraints and for calculating the oil price trajectories corresponding to the two geopolitical strategies:

- In a market flooding scenario, IMACLIM-R does not find a possibility to maintain prices below 50$ for a long time and rather envisage a smooth increasing trend between 60 and 80$, a plateau below 100 $/bbl in 2040 and skyrocketing prices up to 160$ in 2050 during the last decade of the period.
- Under a 'restriction scenario', IMACLIM-R predicts a steep increase of oil prices beyond 100$/bbl after 2020. This increase is followed by an upward trend leading to prices over 200$/bbl in 2030, level at which they stabilize as a feedback of demand and supply-side responses in the oil importing countries and to a steady decline at the end of the period (which continues after 2050).

Fig. 3 - Oil prices in reference scenarios ($/bbl)



1.3.2 Oil prices trajectories, a significant impact on GDP growth

Confronted with different levels of oil prices (that govern gas and coal prices) the growth engine we just describe does not deliver the same growth rates in a scenario without climate policies (Reference scenario R)[9]: 0.95% over 2010 – 2035 in case of low oil prices instead of 0.78% with high prices, 1.33% instead of 1.11% between 2020 and 2035, and 2.23% instead of 2.16% at the end of the period (Table 1). This is the logical consequence of the drain imposed by imports of fossil energy on the European economy: higher exports of non-energy goods are needed to stabilize the European trade balance which implies lower wages and leads to a lower internal demand.

Even the growth recovery after 2030 would not succeed to stabilize unemployment in the EU15: accessing countries demand a fast-catch-up dynamics and growth rates above 3% or 4%. An average EU growth rate below 2% per year would thus imply a growth rate in the EU 15 significantly below 1.5% which would result into average unemployment levels undermining the social stability in the EU, especially in regions with a lower growth than the European average.

Table 1: GDP MER Real - Growth rates (%)

	High oil prices (HOP)	Low oil prices (LOP)
2010-2035	0.98	1.13
2015-2020	0.65	0.97
2020-2035	1.11	1.33
2030-2035	2.16	2.23

1.3.3 Four scenarios to disentangle the specific role of policy variables

To understand how a low carbon transition could generate a sustainable economic recovery in the EU, it matters to disentangle the interplays between the macroeconomic mechanisms activated by various policy tools. We then present here below a succession of policy scenarios leading to a decarbonization profile in line with the claimed EU objective of reducing its CO_2 emissions by half in 2035 compared to 1990, and by 4 in 2050. As shown in Table 2, each of these scenarios correspond to increasingly rich policy packages.

None of these scenarios can be read as realistic. They are numerical experiments on virtual

[9] About the influence of oil prices on economic growth see: Hamilton (2008), Davis and Haltiwanger (2001).

scenarios helping to disentangle the specific role of each option, alone and in combination with others. For policy debates their comparison matters more than the absolute value we find and, because the most critical issue is about the triggering phase, the time profile of the economic consequences matters more than the cumulated effects over the period.

In **scenario V0**, Europe adopts climate centric policies in the energy sector on the supply and demand side. An emission constraint is imposed on the European economy and its resulting shadow price is transformed into a carbon tax imposed in all sectors. The revenues of this tax are given back to taxpayers in a lump sum way. The ‘scarcity rents’, the differences between the marginal abatement costs and the average abatement costs, remain in each industry.

Scenario V1 adds to V0 scenario transport infrastructure policies to modify the dynamics of passenger transport and freight. In V0 scenario infrastructures decisions rest on the same rationale as other production capacities: when infrastructures approach saturation, their expected profitability is enhanced. Investments are triggered to expand the network and this reinforces the modal shares of road and air transportation. In V1 scenario we assume that national and local public authorities, for objectives other than climate goals, invest more on urban forms conducive to ‘soft modes’ and incite a decoupling between production and the freight transport. This mobilizes a complex set of parameters that govern localization patterns (industrial specialization, trade-offs between supply security and ‘just in time’ production, urban and land-use policies, real estate pricing) that are not described in IMACLIM-R. Their result is simply translated through a ceiling on road infrastructures.

Scenario V2 adds to V1 scenario a recycling of the revenues of the carbon tax into lowering the social contributions paid directly or indirectly by labor. In the V0 and V1 scenarios variants, production costs increase beyond the mere carbon price because higher energy costs propagate through the interplay between sectoral production and demand. This propagation effect is counteracted in V2 scenario by the decrease of labor costs.

Scenario V3 adds to the V2 scenario policy packages financial devices meant to reduce the specific risks involved in low-carbon investments and incite to invest in projects with longer return periods. These policies reduce the risk-weighted capital cost of low carbon energies and energy efficiency. In addition to V3 scenario incorporates the development of labor and vocational training policies that accelerate the adaptation of manpower to the new jobs and maximize the share of the low carbon activities satisfied by European production.

Table 2: Scenarios definition

R	Reference Scenario with two variants (High Oil Prices (HOP) and Low Oil Prices (LOP))
V0	Climate Centric Policies (CCP) with two variants (HOP and LOP)
V1	CCP plus Infrastructure policies (CCPI) with two variants (HOP and LOP)
V2	CCPI plus carbon taxation (CCPIT) with two variants (HOP and LOP)
V3	CCPIT plus Financial Devices with two variants (HOP and LOP)

2 Climate-centric policies: the reasons for significant costs

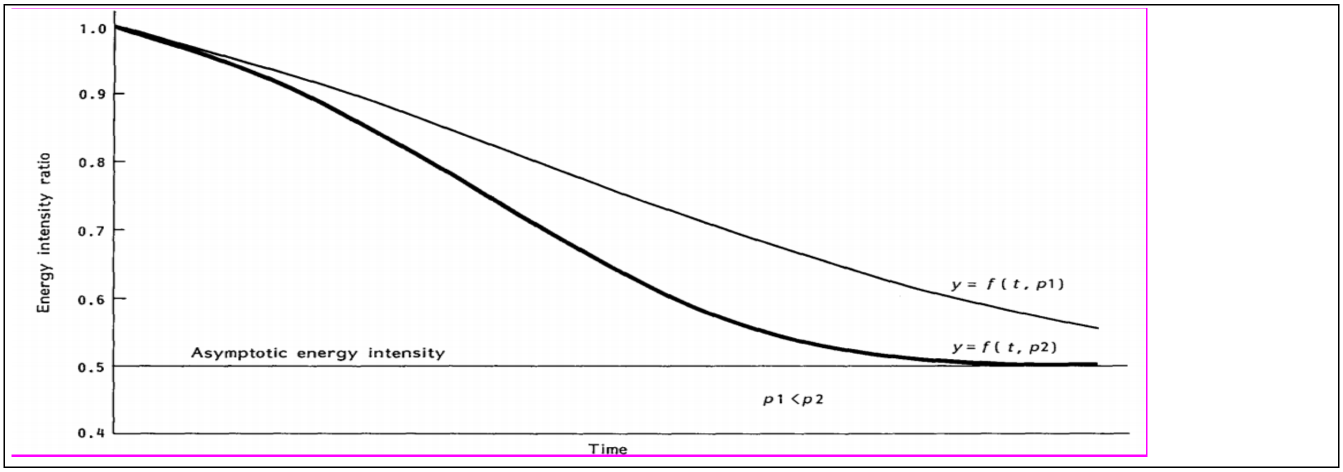
In this section, we consider climate policies like most modeling studies conducted at the margin of a reference scenario independently from any other objective, even though it is possible to assess, ex-post, their co-benefits for example in terms of energy security or local pollution (Clarke et al. 2014). In consistency with established economic wisdom[10] and because most models assume least cost planning under perfect foresight[11], they find that a uniform carbon price is necessary to minimize costs of reaching a given decarbonization target.

Even if it is a virtual scenario with a low probability of realization, it provides a clear and useful benchmark to assess other policy scenarios. It gives a pivotal role to a shadow carbon pricing imposed to all economic sectors through various channels: explicit and ex-ante carbon pricing through taxes, explicit and ex-post carbon pricing through carbon trading, implicit carbon pricing through standards, norms, procurement contracts adopted by public agencies or notional carbon prices used by enterprises for the internal management.
IMACLIM-R introduces the link between non-price policies and carbon pricing through the mechanism pictured in Fig. 4 with an asymptote giving the best technological performance attainable

[10] This shared wisdom is supported by theory only to the extent that compensatory transfers secure that the marginal welfare losses or gains are equated amongst individuals and countries. Otherwise differentiated prices 'à la Lindhall' should be imposed in invert proportion of the income levels (Chichilnisky et al. 2000)
[11] The 'perfect expectation' hypothesis is useful for designing long-term equilibria, but it ignores the anxiety of decision-makers generated by the interplay between uncertainty and inertia in technical systems and institutions (Hourcade & Crassous 2008).

at a given point time. For a given asymptote the energy prices act as an accelerator of the diffusion of this technology (here, the convergence towards the asymptote performance will be lower in the p1 case than in the p2 case).

Fig. 4: Representation of non-price policies in IMACLIM-R



This asymptote can be moved by non-price mechanisms such as norms and standards. This does not constitute a free-lunch because, although they have a lower leveraged cost, low carbon intensive technologies imply higher investments costs and crowd-out other investments which slows down the learning by doing process and productivity in other sectors.

2.1 The rationale for high implicit carbon prices

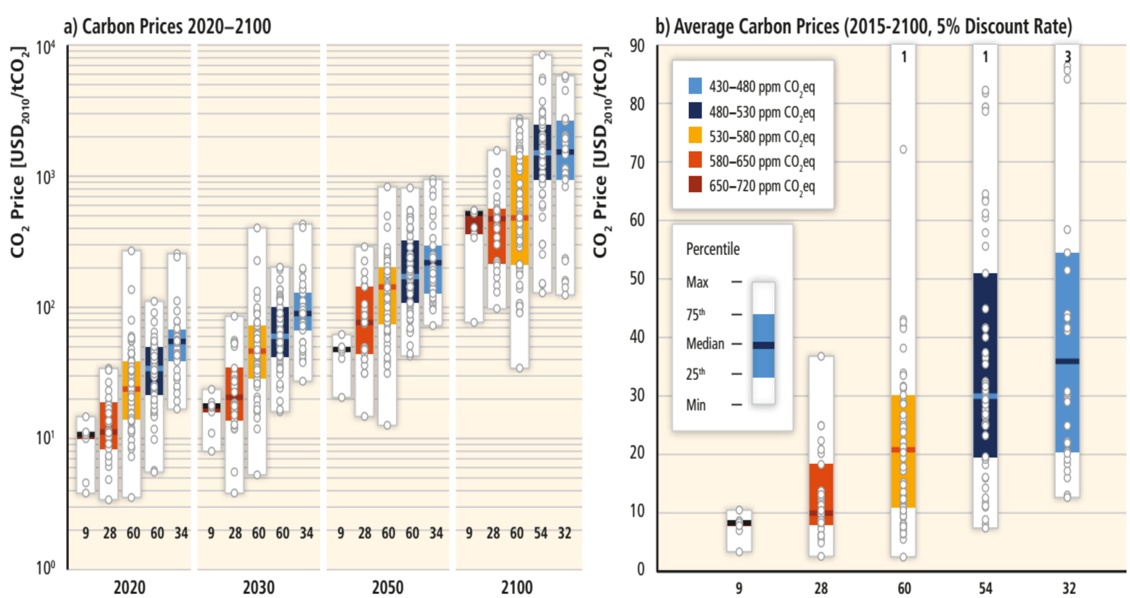
Table 3 displays the level of carbon prices required to achieve the decarbonization objective under assumptions of low or high oil prices in the V0 scenario. The reader can be surprised by carbon prices far higher than those often circulated in public debates, for instance in the report of the High Commission on Carbon Prices (Stern and Stiglitz 2017)[12]. However, these figures are well within the range of magnitude obtained by the IPCC in 2030 (30-400$/tCO2) (Clarke et al. 2014). Between 2030 and 2050, the IPCC prices increase sharply (70-300$/tCO2) and so do our prices after 2035. It is true however that our price trends lay in the upper range of the IPCC price corridors. This is because IMACLIM-R captures the interplay between imperfect expectations behaviors and the inertia of capital stocks and lifestyles. Very high prices are thus needed over the short and medium term to alter the behaviors of economic agents if, like in the V0 scenario, carbon prices are only policy tool.

[12] Note that the corridor of carbon prices for 2030 (US$50–100/tCO2 by 2030) mentioned in the report to achieve the Paris Agreement Target does not consider the uncertainty of oil prices.

Table 3: Carbon prices for V0 scenario (\$/tCO_2)

	High oil prices (HOP)	Low oil prices (LOP)
2015-2020	26	170
2020-2025	49	288
2025-2030	132	248
2030-2035	320	461

Fig. 5: Range of carbon prices in AR5 scenarios (\$/tCO2)

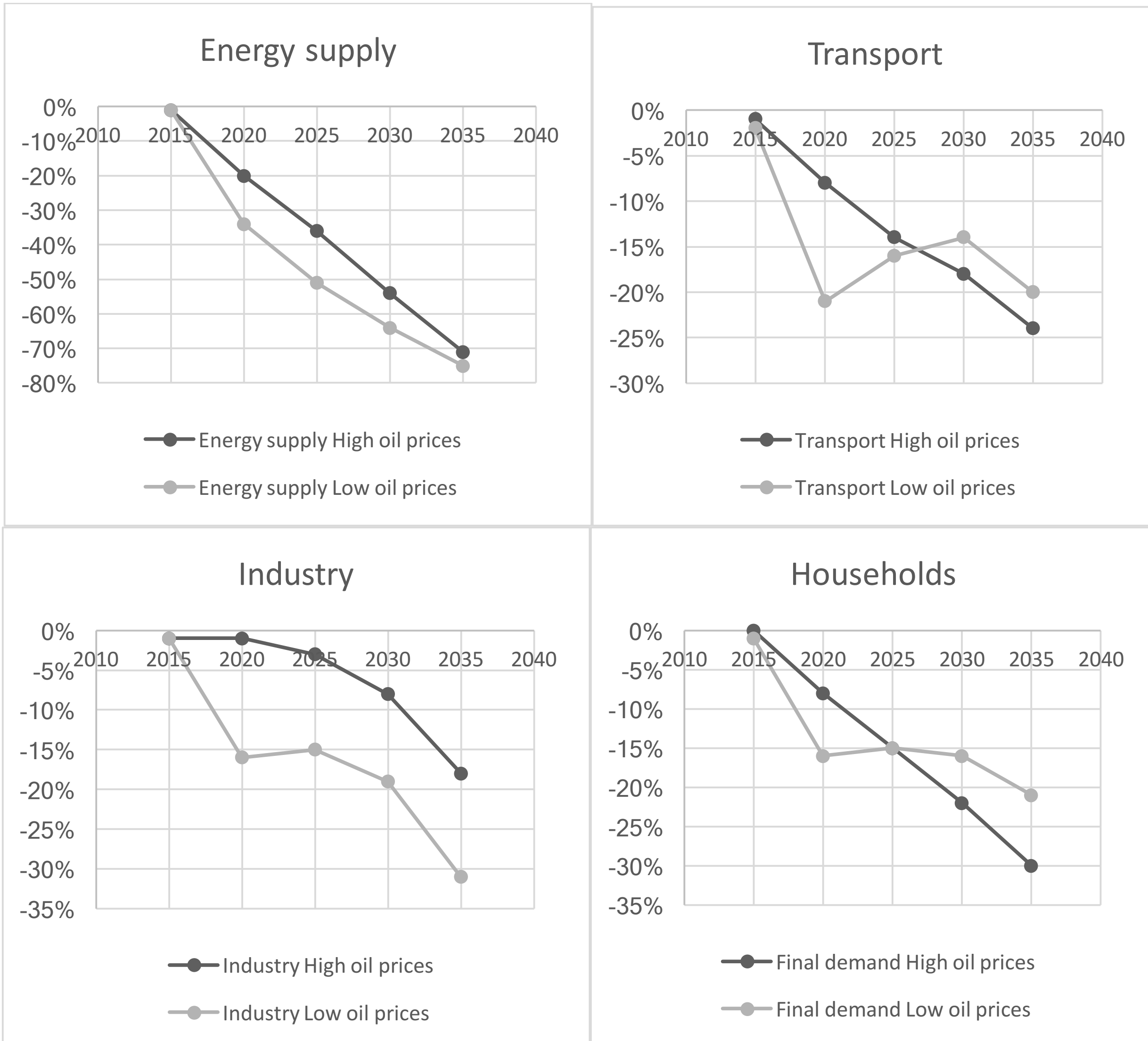


Unsurprisingly, higher carbon prices are needed in the low oil prices (LOP) variant of the VO scenario for achieving the same emission target. The difference is huge over the two first periods with carbon prices 6.5 times and 5.9 times higher in the LOP variant than in the HOP variant. In the latter indeed, high oil prices do part of the 'decarbonization job' for a given emissions profile. A difference of 40\$/bbl corresponds to about 108\$/tCO2 and starting from the HOP variant as a benchmark, the amounts of abatement required are far lower than starting from a LOP variant up to 2025.

This has non-negligible implication for the short term sectoral dynamics (Fig. 6). Taking a HOP variant as a benchmark, the amounts of abatement over the first period (2020) increase from 20% to 34% in the energy supply when passing to a LOP variant, from 7% to 16% in the households sectors and from 7% to 21% in the transportation sector. This tripling of effort in the latter sector is due to the fact that, under the LOP variant, there is a very little slowdown of mobility demand. A very high level of carbon tax is thus immediately needed to de-carbonize transportation activities. This high carbon tax in turn forces other sectors to make more efforts in particular in the industry sector which has to abate its emissions by 15% in 2020. Industry is almost unaffected by the low level of carbon price in the HOP variant.

Interestingly, thanks to the very drastic rise in carbon tax to meet the 2020 target for the LOP variant, the constraint appears slightly relaxed in 2025. Indeed, the carbon tax decreases from 288 to 248 $/tCO2 (Table 3). Therefore, between 2020 and 2030, emissions in the transport sectors show a rebound (Fig. 6).

Fig. 6 Carbon abatement by sector in V0 scenario (grey line for low oil prices (LOP) variant, dark line for high oil prices (HOP) variant) (%)



The plausibility of so high carbon prices is obviously questionable. The increase of households' budget dedicated to energy and transport (Table 5) raises the question of the relative political acceptability of implicit carbon costs and explicit carbon taxes. The first reflex is to consider that the political acceptability of the former will be higher. But, beyond a certain level, the real costs are perceived and this generates a political opposition under the overall feeling that governments did not tell the truth[13]. A carbon tax allows, as discussed below, for lowering the propagation of the

[13]For instance, feed-in tariffs for wind and solar power plants ranging from 60 c$/kWh to 180 c$/kWh corresponds to 60 to 540 $/tCO2.

‘hidden costs’ of a large-scale deployment of command and control measures throughout the economic system and for opening an explicit discussion about the recycling of the revenues of carbon prices.

Table 4: Share of households’ budget dedicated to energy and transport (%)

	High oil prices (HOP)		**Low oil prices (LOP)**	
	R	V0	R	V0
2015	13.2%	13.5%	11.9%	12.5%
2020	14.7%	15.2%	12.4%	19.7%
2025	15.4%	17.1%	12.5%	16.6%
2030	15.7%	17.7%	12.3%	15.2%
2035	15.0%	18.5%	11.6%	16.7%

2.2 From carbon prices to adverse macroeconomic impacts

In both all prices variants, the V0 scenario results in lower GDP growth than in the reference scenario R at every time period (Table 5). This is unsurprising because, in the absence of companion policy to offset this mechanism, higher energy costs propagate throughout all sectors and result in higher production costs (4 to 5% increase for the heavy industry in 2035) and higher selling prices of final goods. Since international competition constrains the possibility of higher wages to guarantee the purchasing power of households (Table 6), the decrease of real wages results into a lower households’ demand. Combined with lower market shares on international markets caused by losses of international competitiveness, this mechanism lowers the demand addressed to the European industry.

Table 5: GDP MER Real - Growth rates in % and in percentage points from the Reference scenario R

	High oil prices		Low oil prices	
	R	V0	R	V0
2010-2035	0.78	0.52 [-0.26]	0.95	0.62 [-0.33]
2015-2020	0.65	0.57 [-0.08]	0.97	-0.83 [-1.80]
2020-2030	1.11	0.86 [-0.25]	1.33	1.81 [+0.48]
2030-2035	2.16	1.51 [-0.65]	2.23	1.57 [-0.66]

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Table 6 - Purchasing power of wages: index 1 in 2001 and decrease from the Reference scenario R (%)

	High oil prices		Low oil prices	
	R	V0	R	V0
2015	1.15	1.14 [-0.9%]	1.2	1.18 [-1.7%]
2020	1.16	1.14 [-1.7%]	1.25	1.01 [-19.2%]
2025	1.2	1.15 [-4.2%]	1.33	1.16 [-12.8%]
2030	1.26	1.18 [-6.3%]	1.42	1.28 [-9.9%]
2035	1.42	1.24 [-12.7%]	1.61	1.34 [-16.8%]

This lower economic growth, combined with the crowding out of investments other than the low carbon ones - which represents a 28% increase of energy-related investments on the supply and demand side - results into a lower rate of increase of global productivity and in an increase of unemployment which is significant after 2025 (+10%), reaching +31% in 2035 (Table 12).

Within this overall picture it is worth noting that, even though the GDP losses are higher in the LOP variant (comparing the LOP variant with and without climate policy), the GDP attained in the LOP variant of V0 scenario is, over the period, 4.4% higher than in a HOP variant of V0 and only 2% lower than in the HOP variant of the reference scenario R. This confirms that climate policies hedge against the economic costs of the volatility of oil prices due to sudden transfers to oil&gas exporting countries (Rozenberg et al. 2010). The underlying mechanism is that, in the LOP variant of V0 scenario, a higher carbon tax allows for retaining a higher part of the oil rent and use it domestically.

However, this positive conclusion is untrue at first period because of the inertia of capital stocks and of behavioral routines. The higher macroeconomic costs at first period in a LOP context come from the households' difficulty to adapt quickly enough their end-use equipment and behaviors to a rise of energy prices that is not offset quickly enough by the decarbonization of energy of transportation systems. The purchasing power of wages is then cut by 24% which has an obvious depressing effect of the final demand and growth (Table 18).

The role of inertia then vanishes along with the penetration of low carbon equipment and V0 returns to positive growth rates (Tables 5). The strong adaptation carried out over the five first years even allows for growth rates above the reference between 2020 and 2030 in LOP variant: an economy now strongly adapted to a high prices of fossil fuels is more easily to the peak of oil prices that occurs during this time period than in the Reference scenario R. This creates a form of rebound effect which has to be overcompensated, after 2030, by skyrocketing carbon prices (from 248 to 461 $/tCO2).

Table 7 – GDP per capita (k$) (in R, V0 scenarios for LOP and HOP variants)

	High oil prices		Low oil prices	
	R	V0	R	V0
2015	22.8	22.72	23.29	23.11
2020	23.23	23.06	24.1	21.87
2025	24.39	23.86	25.63	24.07
2030	25.5	24.71	27.04	25.72
2035	28.28	26.54	30.09	27.72

3 A European green investment trigger scenario

We now try to design progressively an alternative scenario based on the mainstreaming of climate policies within policy packages adopted in search of a more stable growth and a more inclusive development in a globalized economy. For simplicity sake, the modelling exercise still assumes the level of carbon prices to be the same throughout Europe. The major difference with the previous V0 scenario is that climate centric measures leading to the emergence of carbon price (at least implicit) are not the only policy tool.

The intellectual challenge is that the resulting policy-package will be composed of very different layers of measures and that, when demonstrating that it could turn the burden of climate policies into a gain, this might appear as resulting from 'magic trick'. To avoid this risk, we proceed in three steps to isolate the specific impact of each layer:

(i) mainstreaming of climate objectives in structural change policies
(ii) deployment of carbon based fiscal reforms
(iii) reforms of the financial intermediation system

3.1 Mainstreaming climate objectives in structural change policies

One challenge for the European societies is to find a way to secure an inclusive development despite the limits of redistributive policies. If their development pattern generates a high degree of social dualism, increasing public transfers needed to compensate for this trend results into a higher burden either on productive activities or on middle-high income classes thus provoking a 'taxpayer fatigue'. In this Green Transition Scenario (V1), we assume two sets of changes to reorient the EU development pattern into a more inclusive way:

- **Densification of the EU production fabric and development of human capital**: the low carbon transition mobilizes activities which are mostly 'sedentary' in the sense that they are developed in local specific situations (e.g.: a railway system, refurbishment programs). It can thus support a more 'inward oriented' industrialization by developing markets less exposed to international competition through wages. The magnitude of this potential depends upon a) the availability of appropriate skilled manpower[14] and b) the reinforcement, at all levels, of a cooperation between corporations,

14 The unavailability of appropriate skilled workers is for example one of the major constraints limiting the pace of the

middle-size and small enterprises so that most of the segments of the value chain are produced domestically. To capture the impacts of these parameters, we correlated, in our numerical exercises, the share of the sedentary activities (with zero price elasticity to foreign products) with the amount of energy-related investments[15] and we assumed a higher adaptability of the labor force to structural changes implied by the low carbon transition[16].

- **Redirection of infrastructure investments and of spatial planning** to reduce the 'constrained mobility needs' of which importance has been demonstrated in scenario V0. We consider improved traffic regulation, increase of the share of non-gasoline based transportation modes (soft transportation modes, electric vehicles, rail and waterways). In our numerical exercises, we assume that this redirection is critically important to shift mobility trends and control the rebound effect on mobility demand triggered by increases of the energy efficiency of vehicles. This is really a 'redirection' scenario since we assume no increase of the total investment in the transportation sector by comparison with the reference scenario R.

These two sets of policies work synergistically through the interplays between the spatial organization (urban forms, urban systems, links with cities and their rural neighborhood), the commercial networks and the local content of goods and services for the final consumers. This determines both the local employment content of activity and the trends in the freight content of overall production. The freight content is indeed an obstacle to decarbonize the economy [17] which is underestimated in modeling exercises that do not link its evolution to assumptions about the spatial footprint of the production systems.

Obviously, scenario V1 cannot capture in a simple and mechanical way interplays of which real functioning will depend upon the coordination of policies between departments often operating in isolation and across various governance levels (countries, regions, cities). It remains a 'virtual' scenario; however, it helps understanding the move in the 'possibility spaces' at stake in this set of policies.

The carbon tax profile in this V1 scenario is almost identical with this profile in the previous V0 scenario. This might be surprising since V1 scenario incorporates investment infrastructures aiming at

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deployment of energy efficiency in buildings.

[15]Energy-related investments encompass investments for energy supply as well as on the demand side.

[16]Guivarch et al. (2010) explain the macroeconomic costs of climate policies by the labor market flexibility. The notion of flexibly in this context is the pace at which the labor force switches to one job to another. In case of full flexibility, in a certain macroeconomic context, the necessity to switch of jobs does not indeed result into a lower use of labor forces.

[17]For example, Crassous et al. (2006) find pessimistic cost of climate policies in the long run in the absence of modification of the dynamics in freight intensity of growth. The penetration of cheap carbon-free substitutes to gasoline and diesel comes too late to curb down emission trends without curbing down economic growth.

controlling the growth of mobility needs. The reason is that, given the inertia of transportation infrastructures, these investments significantly alter the mobility demand and GHGs emissions trends beyond 20 years only[18]. Before this date, they hardly compensate for the need of higher prices to compensate, *ceteris paribus*, for the higher emissions generated by the 1% higher total output in 2030.

Table 8: Carbon prices ($/tCO2)

	High oil prices (HOP)			**Low oil prices (LOP)**		
	R	V0	V1	R	V0	V1
2015-2020	0	26	28	0	170	173
2020-2025	0	49	49	0	288	285
2025-2030	0	132	136	0	248	224
2030-2035	0	320	334	0	461	416

Although the differences are numerically low, it matters to understand why, despite a slightly superior carbon tax profile (Table 8), hence a higher burden on production costs, in both variants V1 scenarios achieves a slightly superior growth rate than V0 scenario (Table 9). Unemployment is respectively 1.9% and 0.6% lower in 2020 in HOP and LOP variants, 2.3% and 5.7 lower in 2035 (Table 12). Some of the mechanisms at play in this result will indeed be magnified in V2 and V3 scenarios:

- **Lower mobility needs and lower freight content of production reduces oil imports and allows for higher wages since EU is less forced to export to meet the same trade balance.** Even though infrastructure decisions deliver the bulk of their benefit over the medium and long term, some of them like traffic management or speed regulation lower the energy expenditures of households over the short term. The external transfers due to oil imports are reduced by 13% in 2020 and 34% in 2035 between V1 and V0 scenarios.

- **Higher energy investments create a higher domestic demand for activities thanks to a faster adaptation of labor forces**. The degree of exposure of the overall economy to international

[18] On the same topic, see Waisman et al. (2012a).

competition decreases which limits the adverse effect of higher production costs (higher wages and higher energy costs) in terms of market shares (both in the European internal market and in foreign markets).

Table 9: GDP MER Real - Growth rates (%)

	High oil prices			**Low oil prices**		
	R	V0	V1	R	V0	V1
2010-2035	0.78	0.52	0.56	0.95	0.62	0.67
2015-2020	0.65	0.57	0.64	0.97	-0.83	-0.78
2020-2030	1.11	0.86	0.92	1.33	1.81	1.92
2030-2035	2.16	1.51	1.49	2.23	1.57	1.56

The slight increase of economic growth between V1 and V0 scenarios obviously slows down the crowding out effect on non decarbonation related investments and the decrease of overall productivity from the reference scenario R. However, compared with a no policy scenario, a low carbon transition mainstreamed with structural change policies, has a negative impact that increases the risk of long depression in the EU. The good news however is that the comparison between V1 and V0 scenarios however helped to detect the negative and positive mechanisms at play. The question is then how to reduce the former and magnify the latter. Two main tools are at our disposal to do so, fiscal policies and finance. We analyze them in Variants V2 and V3 scenarios.

3.2 When climate friendly fiscal reforms come into play

The main reason why the two above policy packages, despite very optimistic assumptions about the penetration of energy efficiency and about the deployment of structural policies still result into a negative impact on growth by comparison with the Reference scenario R is the adverse mechanisms resulting from higher production costs.

V0 and V1 scenarios actually assume that the revenues due to the difference between the marginal production cost resulting from carbon abatement and the average production cost are retained by industry with no guarantee that they are optimally recycled into the economy. This is a well-established, although often forgotten, result in public economics that the ultimate cost of a tax (of any cost increase of a production factor) is higher than its direct costs. This is due to (i) the propagation of cost increases throughout the inter-industrial matrix, (ii) the rents generated by the different "pass-through" capacities of the various sectors (share of the cost increase passed through the downstream sector) and (iii) the dead-weight losses for consumers, the so-called Harberger's triangle.

The only way to prevent the propagation mechanism is to raise an explicit carbon tax and to recycle its revenues into the economy so as to decrease in the same proportion a distortionary taxation falling on production. The optimal recycling is country specific and this is the reason why, in its article 136, the Paris Agreement states that carbon pricing *"applies to non-party entities, and is not binding upon countries that are parties to the UNFCCC."* We could not carry out a precise study for each country within the scope of this study. Otherwise, this would have required to represent the country specific energy pricing policies and very likely, differentiated carbon prices. This is why we considered the most common option in empirical literature, namely a switch between carbon taxes and payroll taxes.[19]

Thanks to this switch, the rise in production costs caused by the carbon tax is lower. It even declines for the more labor-intensive industry (80% of the value added) that benefits more of the decline of the tax burden on labor. It is far lower on energy intensive industry. This explains why the production cost of composite goods can decline, at certain time periods. Actually, the net result depends upon the rate of increase of net wages allowed by this lower tax burden (if the increase of net wages absorb the cut in labor taxes, there is no decrease in production costs). This rate is governed by the wage/unemployment elasticity which actually captures the power relationships in the labor market.

For a given price elasticity of energy efficiency in the production sector (which, at this level of aggregation encompasses also structural changes), the penetration of energy efficiency in industry is accelerated because the ratio between the relative cost of energy and labor costs is significantly higher thanks to the recycling of the carbon tax than in the absence of this recycling. A virtuous cycle can thus be launched thanks to the reconciliation between the demand-side and supply-side policies: increase of labor per unit of output due to lower gross labor costs -> higher employment for a given activity level -> increase of net wages -> higher households' purchasing -> stability or decrease of the domestic demand covered by foreign products because the production costs do not increase -> higher demand addressed to the EU production system.

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[19] There is plentiful literature on the double dividend and on carbon trading since the three indicates. This literature is regularly synthetized in IPCC reports: see Hourcade, Richels and Robinson, IPCC AR2, Chap 6 pp 272-274 chap 7 pp 303-317; Hourcade and Shukla, IPCC AR3, Chap 6 pp512-522; Gupta and Tirpak, IPCC AR4 Chap 13 pp 753-769 and Clark and Jiang, IPCC AR5, Chap 6 Ppp 455-456

Table 10: Carbon prices ($/tCO2)

	High oil prices				Low oil prices			
	R	V0	V1	V2	R	V0	V1	V2
2015-2020	0	26	28	30	0	170	173	208
2020-2025	0	49	49	54	0	288	285	379
2025-2030	0	132	136	156	0	248	224	254
2030-2035	0	320	334	384	0	461	416	425

Table 11: GDP MER Real - Growth rates (%)

	High oil prices				Low oil prices			
	R	V0	V1	V2	R	V0	V1	V2
2015-2035	**0.98**	**0.73**	**0.76**	**0.77**	**1.13**	**0.63**	**0.67**	**1.03**
2015-2020	0.65	0.57	0.64	0.73	0.97	-0.83	-0.78	0.57
2020-2030	1.11	0.86	0.92	1.08	1.33	1.81	1.92	1.51
2030-2035	2.16	1.51	1.49	2.13	2.23	1.57	1.56	2.05

Logically though, V2 scenario generates a higher GDP growth and a lower unemployment than V1 and V0 scenarios (Table 11). The differences are small in a HOP variant (0.04 and 0.01 percentage point on average over the period) and significant in a LOP variant (0.37 and 0.40 percentage point. In 2035, the total GDP is 7.1% higher in V2 scenario than in V1 scenario which explains the necessity of a 15% percent higher carbon price (384$/tc) (Table 10). The critical result for the inclusiveness of development is a significant reduction of unemployment at the end of the period (-26% in 2035) (Table 12). These optimist results must be qualified by the fact that this reduction is small up to 2025; up to this date indeed the low level of carbon taxation does not allow for significant cuts in labor taxes.

The key comparison is obviously between V2 scenario and the reference scenario R. Over the period, V2 scenario generates results systematically into a lower growth rate: a small minus 0.01% per year in a HOP variant and a more significant minus 0.08% in a LOP variant. Despite a higher labor intensity of growth, the resulting unemployment is significantly higher in the LOP variant (+13% in 2035 with a peak of 19% in 2020) and slightly higher in the HOP variant.

This means that the recycling scheme retained in the simulation is not efficient enough to prevent the increase of production costs and generate a strong form of double dividend.

Table 12: Variation in the unemployment rate compared to the Reference scenario R

High oil prices						Low oil prices					
Senario	2015	2020	2025	2030	2035	Scénario	2015	2020	2025	2030	2035
R	1	1.00	1.00	1.00	1.00	R	1	1.00	1.00	1.00	1.00
V0	1	1.02	1.06	1.09	1.28	V0	1	1.57	1.40	1.31	1.56
V1	1	1.00	1.06	1.09	1.25	V1	1	1.56	1.30	1.18	1.42
V2	1	0.98	1.01	0.99	1.00	V2	1	1.12	1.06	1.00	1.07
V3	1	0.90	0.75	0.78	0.79	V3	1	0.94	0.90	0.88	0.79

These results should not be over-interpreted since slightly different parameter choices and a more careful design of the recycling scheme (incorporating country specifics) would reverse their sign. However, our experience with the IMACLIM-R model confirms the conclusions of the many works about double dividend, namely the fact that, when this policy variant leads to an increase in total output, this increase is limited. It is all the more limited than part of the revenues of the carbon tax should be used to offset adverse distributional effects (Combet et al. 2010). Recycling carbon tax revenues is thus critical for conducting climate policies at almost zero aggregate macroeconomic costs. But it is not apt to trigger a significant “Green Growth” dynamics especially because of the fact that its ‘second dividend’ is not strong enough over the short term to offset the costs due to the inertia of socio-technical systems.

3.3 When climate finance comes into play

In the economic framework utilized so far it would be possible to generate Green Growth perspectives using even more optimistic assumptions about learning-by-doing process and overall endogenous feedbacks between technical change and growth. However, beyond the fact that these assumptions would be made for pure convenience and be suspected of being unrealistic, they would not solve the ‘triggering phase’ problem because their benefits would not span quickly enough over the short term to offset the residual negative impacts of carbon prices that have not been offset by a well-targeted recycling of their revenues.

Over the short term, the only margin of freedom is both to trigger a strong decarbonisation process with lower carbon prices and to look seriously how climate policies could help reduce the other sources of 'overall efficiency gap' than those so far evoked in climate change economics. The low carbon scenarios have generally been developed so far with no consideration of ongoing macroeconomic discussion about the fault lines of the world economy (Rajan 2010) and the alerts of top level macroeconomists about risks of i) 'depression economics' (Krugman 2010) ii) secular stagnation (Summers 2015) and iii) the rising number of 'discontents' of the globalization process (Stiglitz 2002). This deprives from examining how, because it requires a huge redirection of investments, the low carbon transition could help reduce the gap between the 'propensity to save' and the 'propensity to invest' in long term productive assets and infrastructures which is pinpointed as one major source of fragility of the world economy (IMF 2013).

The low propensity to invest results from three intertwined features of our modern economies: i) risk uncertainty, ii) a "shareholder business regime" and iii) a financial intermediation system cautious to transform cash balances into long-term assets (Aglietta 2014, IMF 2013). This penalizes the low carbon investments and undermines the incentive efficacy of carbon prices. Indeed, ***techniques are not on a shelf, ranked in increasing order of their levelized costs*** and switching carbon prices might be higher than those needed to change this merit order. Low carbon investments (LCIs) with ***high capex and long payback periods*** might not be adopted because of ***their risks in a context of uncertainty*** about the duration and costs of their construction phase and about their future revenues. In case of 'bad surprise', firms and economic agents can see their operating account deficits reaching a 'danger line' they refrain from crossing. This implicit danger line explains households' i) demand for very short payback periods for investments in energy efficiency, ii) the behavior of SMEs with limited access to finance beyond self-finance or iii) of firms who anticipate that, some shareholders losing confidence, their value might fall sharply with risks of bankruptcy or of hostile takeover.

In this policy package of the V3 scenario we thus incorporate a financial device that lowers investment risks in low carbon projects. Redirecting savings towards the low carbon transition could narrow the excess of savings over investments by indicating in a credible manner where the investments should go. This would accelerate the trickling down of savings into the productive economy, immediately reduce the existing excess capacities and offset the crowding out effect on other productive sectors by increasing the savings dedicated to long-term investments. Doing so they would magnify the positive effects of measures contained in V1 and V2 scenarios.

Table 13: Carbon prices ($t/CO2)

	High oil prices					Low oil prices				
	R	V0	V1	V2	V3	R	V0	V1	V2	V3
2015-2020	0	26	28	30	11	0	170	173	208	152
2020-2025	0	49	49	54	77	0	288	285	379	350
2025-2030	0	132	136	156	130	0	248	224	254	233
2030-2035	0	320	334	384	390	0	461	416	425	461

We will not in this report enter into the precise design of such a device of which we give a sketch in Box 1. The basic principle is to consider part of the upfront investment costs without waiting uncertain and delayed revenues of the reduction carbon emissions, which is one of the recognized limits of the clean development mechanism (Hourcade et al. 2012). This opportunity can be seized if ***States and sub-sovereign entities undertake gently to reduce initial risks in these shifts by providing public guarantees in a coordinated way.*** Public guarantees, implicit or explicit, do not entail a large burden on tax payers, and have always been important in underwriting global transformations in history (railways, electricity, telecommunications).

To hedge against the risk of political arbitrariness in the allocation of these guarantees and secure their overall economic efficiency they should be articulated around a robust Measurement, Reporting and Verification (MRV) process and around an agreed upon per ton value of avoided emissions. This value should express the *social, economic, and environ- mental value(s) of mitigation (SVM) actions [and] their co-benefits to adaptation, health, sustainable development* as recommended by the para 108 of the decision of the 'Paris Agreement'. It is a notional price that represents the present value of the trajectory of shadow prices of carbon for meeting the 2°C target augmented by the co-benefits of mitigation. This comes to give upfront to the investors the 'reward' that the policy-makers cannot commit to give through explicit carbon prices aligned with this trajectory (see Box 1 for a short discussion).

The reduction of the capital costs of a given technology depends actually on its lifetime. At the aggregate level, the results obtained in IMACLIM-R are a 90$/t value for an average 15 years lifetime of investments and a 23% cut in investments costs of low carbon technologies which is equivalent to halve the interests' rates.

The main result, reported in table 14, is that the GDP growth is significantly higher than in the Reference scenario R at all time periods and, politically more important, including at first period between 2015 and 2020. The growth rate is still below 2% before 2020 which means that there is no 'economic miracle', but this positive trend continues over the following decade, and stagnation phase in the EU is over after 2030 with a 4.3% growth rate. The latter figure looks very optimistic nowadays but it is worth recalling that this allows for a 2.5% growth rate in EU15 which is the level needed to end with the structural unemployment in many countries of this region (France, Greece, Italy, Spain, and Portugal).

To understand the mechanisms at play, let us come back to the time profile of the carbon tax in the V3 scenarios. In both all prices variants, the carbon taxes are slightly higher than in V2 scenario after 2030. This is due to the need to offset the impact of higher growth rate on final energy demand but its burden on households and enterprises is lower. More important for the political acceptability of climate policies is that they significantly lower at first period than in other carbon constrained scenario. To put it in another way, with lower investment risks, the higher amount of investments is triggered by a given level of carbon price. This changes the political economy of tax reforms. The difference between a real carbon price and a shadow carbon price is that the former hits vested interest whereas the latter redirects. The difference is impressive in the HOP variant with a tax one third lower than in V2 scenario. The difference is significant by less impressive in the LOP variant in which the carbon tax should reach 152$. This is the mechanical result of the fact that the carbon tax has to compensate for the low level of the prices of fossil fuels.

This means that a SVMA higher that 90$/t (around 150$/t) should be adopted with the corresponding amount of public guarantees to launch the transition with the same time profile of carbon taxes over the two first decades. But this is a problem of policy implementation and does not change the fact that this policy package can generate a significant higher growth over the short run which is the major obstacle to triggering action.

Table 14: GDP MER Real - Growth rates (%)

	High oil prices					**Low oil prices**				
	R	V0	V1	V2	V3	R	V0	V1	V2	V3
2015-2020	0.65	0.57	0.64	0.73	1.89	0.97	-0.83	-0.78	0.57	2.05
2020-2030	1.11	0.86	0.92	1.08	2.13	1.33	1.81	1.92	1.51	1.83
2030-2035	2.16	1.51	1.49	2.13	4.3	2.23	1.57	1.56	2.05	4.47
2015-2035	**0.98**	**0.73**	**0.76**	**0.98**	**2.07**	**1.13**	**0.63**	**0.67**	**1.03**	**2.075**

However, the increase of carbon prices is not the only one obstacle to deploying mechanisms leading to this positive outcome. The low carbon transition described in V3 scenarios represent indeed an investment shock of which apex, in 2025, is a 70% and 95% higher than in the reference scenario R in HOP and LOP variants respectively (these costs include investments in electricity generation, transmission and distribution, energy efficiency, other energy investments, transportation investments and upstream industrial investments for material processing and machinery). Passed this shock the incremental investment costs reduce to 9% and 15% only.

Over the triggering phase of the low carbon transition, the critical issue is the compatibility of this level of investments with public budget constraints. The funding needs at stake are the sum of the incremental investment costs and of the redirection of a share of the investments anticipated in the Reference scenario R (between 30% and 35% depending on the scenario variant). They are between 89$ and 126G$ in the HOP and LOP variants in 2020 and about 180$ in 2025. The advantage of public guarantees is that they are exerted only in case of failure of the projects. With a 100% rate of success their burden on public budgets is null. Assuming a 20% risk of failure (a conventional ratio) a public guarantee of 5$ is thus composed of 1$ of paid-in capital that appears as a debt in the public accounts and 4$ of callable capital. Assuming a very conservative leverage of 2 on private capital, 1$ of paid-in capital would then lever 10$ of investments (the Junker Plan performs a leverage ratio of 15). Thus, between 8 to 13$ of paid-in capital in 2020 and 28$ in 2025 would suffice in leveraging the needed funds. These amounts have to be compared with the 34G$ yielded by a small 0,01$ tax on fossil fuels in the EU. Ultimately, a low carbon transition supported by the couple public guarantees + SVMA would thus improve public budgets: assuming a low 33% of tax on the revenues yielded by the generated project (and ignoring their spill-over effects on economic activity) and a high 20$ default rate, 1$ of paid-in capital would yield 1.33$ of tax revenues.

Over the long term, the critical issue for the economic viability of the low carbon transition is to what extent extra energy investments (which are over the period one third higher than in the Reference scenario R) crowds out other productive investments and slow down the productivity growth in the non-energy related activities. Mechanically, this crowding out is lowered by the increase of GDP growth and by the fact that, thanks to the financial devices at play, part of the European savings, instead of going into the ‘world pool’ of capital and in real estates are invested in European infrastructures. The maximum of reduction of non-energy related investments is 5% in 2025 and this reduction is a negligible 0,003% in the HOP variant against 1% only in the LOP variant. Despite the fact that we did not consider any spillover effect of innovation in mitigation activities on other productive sectors, the long term negative impact of the net crowding out on the European growth engine are overcompensated by the following virtuous circle over the period, which is made up of all the policy components of V0, V1, V2 and V3 scenarios:

i) Lower oil and gas imports with lower transfers of income outside Europe and lower exports needed to equilibrate the EU trade balance.
ii) A more inward oriented economic strategy with a higher share of 'non-exposed activities'.
iii) Higher wages, higher households demand thanks to (i) and (ii) and higher terms of trade (purchasing power of an hour worked in terms of international goods).
iv) A higher demand addressed to the European Economy thanks to higher investments and higher household demand and lower production costs in most sectors thanks to the recycling of the revenues of the carbon tax.
v) Higher employment triggered by the higher demand to the European Economy and to lower costs of labor relative to other production factors.
vi) The medium and long-term overall productivity effect of higher productivity of energy as a production factor.
vii) Improved public budgets thanks to the fact that only the share of public guarantees that bear on public budgets are easily compensated by the tax revenues generated by the guaranteed investments; this allows for (slightly) lower the overall tax burden on GDP.
viii) The long-term gains from learning by doing on the production of equipment due to higher investments in all sectors triggered by higher growth and cuts of investment risks in the energy related sectors. This accelerates of the catch-up of the EU economy.

Actually, the most important result, for the economic and political stability of Europe and the perception of climate policies as a lever for a sustainable and inclusive development is that the fact that this package reduces by 10% and 6% the unemployment at first period in the HOP and LOP variants, respectively and by and 20% and 12% after 2030.

Conclusion: Policy insights from and beyond modeling exercises

The conclusions of this study can be interpreted through two lenses. One gather advocates of enhanced climate action and the second one the climate resigned people for whom the priority is to draw Europe out of pressing economic and political tensions.

For the pro-climate action advocates, this study confirms that launching now ambitious climate policies could provide substantial co-benefits (growth, jobs, energy security) if the set of price and non-price policies they argue for is reinforced by financial devices to de-risk low-carbon investments. However, it also alerts that this positive outcome requires very specific preconditions without which a real burden would be imposed on the European economies especially over the triggering phase of ambitious climate policies: fiscal reforms to make high and generalized carbon prices politically and macro-economically sustainable, standards and norms to promote energy efficiency, redirection of infrastructure policies, commitment of countries to provide public guarantees in function of a social value per ton. But these conditions will not be achieved for climate only objectives. This is why it matters to borrow the lens of the climate resigned.

Interpreted through these lens, the core message of this study is that climate policies can respond part of their short-term concerns about the fragility of the economic recovery and of the cohesion of the EU by accelerating the trickling down of the savings towards the European industrial fabric. They can do so, despite the constraints on public budgets, by underwriting investments with liquid financial instruments backed on secure climate remediation assets so as to upgrade the financial actors engagement (pension funds, insurance companies and bond markets) to fund low-carbon development projects now bankable thanks to the decrease of their risk-weighted capital cost. Passing this triggering phase will allow for a confidence circle, amongst EU member states and within each country, nurtured by the deployment of a development model that will be (i) more labor intensive, (ii) more inward oriented, (iii) more resilient to external economic and political conditions including the oil prices, (iv) more inclusive thanks to better infrastructures and with a higher level of energy security.

The operational ways of maintaining this confidence circle are beyond the scope of this study. But it is possible to identify three major areas of reflection:

- Public guarantees on low carbon investments can be one major component of an increased common European budget to deploy a climate colored 'Junker Plan' targeted to reinforcing the European social cohesion,
- The harmonized increase of carbon prices, facilitated by the generation of new credit facilities and the access to new classes of assets can be a leeway for harmonizing progressively the taxation on labor and the funding modes of social security.
- The decrease of risk-weighted capital cost through public guarantees can facilitate the reform the EU-ETS. This system functions today as a race to the bottom mechanism whereby the setting of global targets and the share of auctioned allowances cannot but be influenced by the political bargaining of the sectors and countries the most hurt by higher energy prices.

What is at stake here is a paradigm shift in climate policies towards positive pricing devices that launch in due time the right and strong incentives to decision-makers while not hurting less vested interests and offering them compensations more credible than transfers relying on the 'goodwill' of taxpayers. It is possible indeed to offer households and enterprises trapped by past decisions or countries relying on important fossil energy resources, the access to a new class of climate remediation assets. This demands institutional innovations beyond the scope of this numerical study but that are implicitly needed to deploy the economic trajectories it describes (see Box n°2).

Actually, this study translates in the European context the Cancun's paradigm shift adopted by the UNFCCC COP16 Cancun. That moves from a 'burden sharing approach' to a 'equitable access to development principle'. However, because it purposefully envisages a unilateral European climate policy to demonstrate that their triggering should not be postponed even in the absence of world agreement, it does not go to the logical end of this paradigm shift. But it lays the basis for establishing an instrument of trust between developed and developing countries to trigger a wave of low carbon investments, with large positive impacts on global economic growth, employment and poverty reduction.

The articulation of public guarantees and SVMA analyzed in this report could be indeed used by a ***Group of Initiatives for Climate Finance (GICF)*** composed of willing developed and developing countries to (i) catalyze global savings to finance sustainable low-carbon infrastructure and climate resilient development (Paris Agreement (P.A.), Article 2) and (ii) help developing countries to actualize their Nationally Determined Contributions (NDCs) by expanding their access to capital markets at lower cost and longer maturities, and by creating pipelines of projects through which their industry, cities and local communities. Such mechanism will advance the UN's 2030 Agenda and achieve the Sustainable Development Goals (SDGs).

Doing so, the European Union could really take the leadership in climate policies, with a high level of political credibility thanks to the support of the European citizens reassured by tangible and short term proofs that of the benefits of investing for building a less risky and more desirable future.

Appendix: detailed figures

1. GDP

Table 15: GDP MER Real - Growth rates (%)

High oil prices

Scénario	2015-2035	2015-2020	2020-2030	2030-2035
R	0.78	0.65	1.11	2.16
V0	0.52	0.57	0.86	1.51
V1	0.56	0.64	0.92	1.49
V2	0.77	0.73	1.08	2.13
V3	1.61	1.89	1.48	4.13

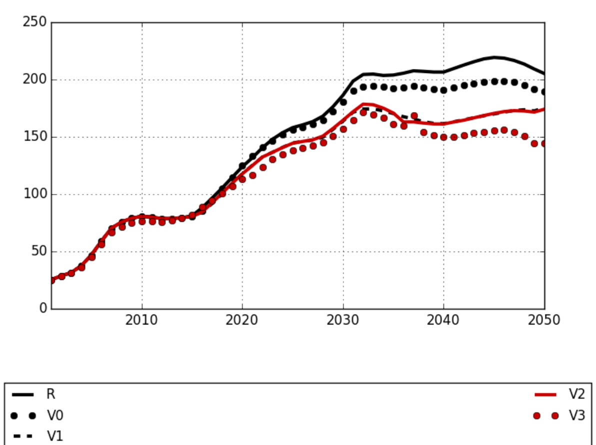
Low oil prices

Scénario	2015-2035	2015-2020	2020-2030	2030-2035
R	0.95	0.97	1.33	2.23
V0	0.62	-0.83	1.81	1.57
V1	0.67	-078	1.92	1.56
V2	0.87	0.57	1.51	2.05
V3	1.81	2.05	1.83	4.47

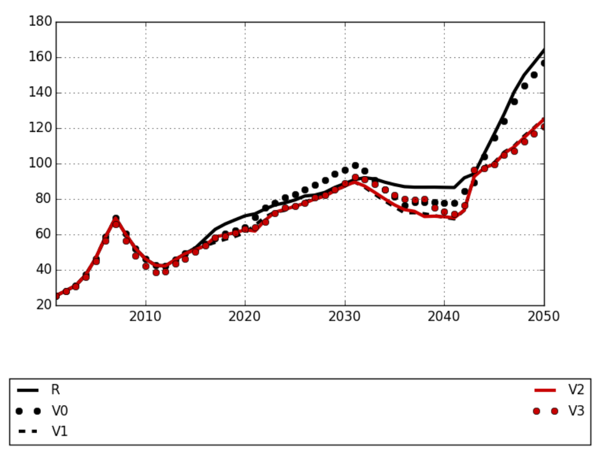
2. Oil prices

Fig. 7: Oil prices ($/bbl)

High oil prices



Low oil prices



3. Carbon tax

Table 16: Carbon tax ($/tCO2)

High oil prices					Low oil prices				
Scénario	2015-2020	2020-2025	2025-2030	2030-2035	Scénario	2015-2020	2020-2025	2025-2030	2030 -2035
R	0	0	0	0	R	0	0	0	0
V0	26	49	132	320	V0	170	288	248	461
V1	28	49	136	334	V1	173	285	224	416
V2	30	54	156	384	V2	208	379	254	425
V3	11	77	130	390	V3	152	350	233	461

Table 17: Carbon tax revenues (G$)

High oil prices						Low oil prices					
Scénario	2015	2020	2025	2030	2035	Scénario	2015	2020	2025	2030	2035
R	0	0	0	0	0	R	0	0	0	0	0
V0	0	68	300	520	1193	V0	0	1160	833	737	1820
V1	0	73	307	522	1524	V1	0	1154	798	617	1649
V2	0	79	378	583	1524	V2	0	1470	971	644	1712
V3	0	89	353	565	1513	V3	0	1260	866	736	1872

4. Wages over price index

Table 18: Purchasing power of wages (wages over pind, index 1 in 2001)

High oil prices						Low oil prices					
Scénario	2015	2020	2025	2030	2035	Scénario	2015	2020	2025	2030	2035
R	1.15	1.16	1.2	1.26	1.42	R	1.2	1.25	1.33	1.42	1.61
V0	1.14	1.14	1.15	1.18	1.24	V0	1.18	1.01	1.16	1.28	1.34
V1	1.14	1.15	1.16	1.20	1.25	V1	1.18	1.02	1.18	1.32	1.37
V2	1.14	1.16	1.19	1.26	1.40	V2	1.18	1.17	1.28	1.40	1.53
V3	1.19	1.28	1.32	1.40	1.61	V3	1.22	1.28	1.38	1.53	1.78

5. Investment

Table 19: Total investment flows (incorporal investment excluded) (G$)

High oil prices						Low oil prices					
Scénario	**2015**	**2020**	**2025**	**2030**	**2035**	**Scénario**	**2015**	**2020**	**2025**	**2030**	**2035**
R	2240	2293	2391	2472	2677	**R**	2240	2341	2489	2618	2861
V0	2240	2283	2336	2381	2475	**V0**	2240	2096	2324	2479	2564
V1	2240	2290	2352	2407	2500	**V1**	2240	2101	2342	2519	2606
V2	2240	2299	2367	2443	2587	**V2**	2240	2206	2407	2572	2710
V3	2240	2398	2457	2567	2217	**V3**	2240	2311	2515	2732	3082

Table 20: Energy investment (bn$)

High oil prices						Low oil prices					
Scénario	**2015**	**2020**	**2025**	**2030**	**2035**	**Scénario**	**2015**	**2020**	**2025**	**2030**	**2035**
R	111	142	173	187	203	**R**	111	128	147	157	176
V0	111	147	212	219	205	**V0**	111	192	220	176	162
V1	111	146	206	211	199	**V1**	111	192	207	168	160
V2	111	149	215	212	198	**V2**	111	192	209	188	156
V3	111	181	295	249	209	**V3**	111	211	286	228	203

Table 21: Total investment excluding energy(bn$)

High oil prices						Low oil prices					
Scénario	**2015**	**2020**	**2025**	**2030**	**2035**	**Scénario**	**2015**	**2020**	**2025**	**2030**	**2035**
R	2577	2546	2515	2501	2485	**R**	2577	2560	2541	2531	2512
V0	2577	2541	2476	2469	2483	**V0**	2577	2496	2468	2512	2526
V1	2577	2542	2482	2477	2489	**V1**	2577	2496	2481	2520	2528
V2	2577	2539	2473	2476	2490	**V2**	2577	2496	2479	2500	2532
V3	2577	2507	2393	2439	2479	**V3**	2577	2477	2402	2460	2485

6. Energy-intensive industry

Table 22: Production prices evolution

High oil prices						Low oil prices					
Scénario	**2015**	**2020**	**2025**	**2030**	**2035**	**Scénario**	**2015**	**2020**	**2025**	**2030**	**2035**
R	0.861	0.903	0.92	0.952	0.966	**R**	0.826	0.848	0.853	0.886	0.906
V0	0.86	0.91	0.93	0.965	1.00	**V0**	0.829	0.886	0.89	0.921	0.95
V1	0.862	0.897	0.913	0.945	0.98	**V1**	0.829	0.879	0.875	0.9	0.936
V2	0.862	0.896	0.912	0.942	0.97	**V2**	0.829	0.867	0.871	0.894	0.926
V3	0.869	0.904	0.91	0.929	0.91	**V3**	0.826	0.872	0.868	0.901	0.91

7. Non-energy intensive industry

Table 23: Production prices evolution

High oil prices						Low oil prices					
Scénario	**2015**	**2020**	**2025**	**2030**	**2035**	**Scénario**	**2015**	**2020**	**2025**	**2030**	**2035**
R	0.856	0.875	0.88	0.906	0.919	**R**	0.841	0.852	0.855	0.89	0.919
V0	0.855	0.873	0.872	0.891	0.893	**V0**	0.837	0.809	0.838	0.882	0.882
V1	0.855	0.867	0.862	0.880	0.881	**V1**	0.837	0.805	0.83	0.874	0.881
V2	0.855	0.866	0.857	0.873	0.869	**V2**	0.837	0.792	0.814	0.867	0.872
V3	0.850	0.828	0.803	0.799	0.713	**V3**	0.841	0.76	0.753	0.805	0.786

Box 1: From SVMAs to the per ton guaranty

The notion of Social Value of Mitigation Activities result from a scientific and diplomatic process that led to the adoption of the Paragraph 108 of the decision of the P.A. where Parties recognize 'the social, economic and environmental value of mitigation actions and their co-benefits to adaption, health and sustainable development'. This definition translates that the shared objective of the international community is to align climate policies with an equitable access to sustainable development (see sections on SVM in the Stern-Stiglitz report on carbon pricing).

The valuation of both the carbon component and the co-bene t component of the SVM will fall necessarily within the competences of each country since it will express its willingness and capacity to pay. For India for example Shukla et al. assess a SVM of 20$ in 2020 reaching 70$ in 2040 whereas the applicable carbon prices would be only 3$ in 2020 and 18$ in 2040 in 2040 (Shukla et al 2011). Such differences exist within the EU countries at a far lower extent. The key issue is whether it is possible to agree on an identical value for all cross borders investments that would represent the necessarily higher willingness and capacity of the international community to pay for the 2°C target. If we set aside the international co-benefits of reaching this target, this value can be calculated on the basis of the trajectories of marginal costs of carbon derived from the 900 scenarios registered by the last IPCC report (IPCC 2014). There is a wide range of costs but the difference between the low and high bounds of the maximum likelihood corridors of the database, corresponding of different degree of technological optimism is not that wide. It could be reduced, to a range far below 1 to 2, by putting out this data base those scenarios that are purely exploratory in nature.

The calibration of the support to a project per ton of avoided emission, the Social Value of Mitigation Activities, is the present value of the retained SVM trajectory and depends on the discount rate and of the lifetime of the project. Table 1 gives the results for contrasted 5% and 2% public discount rates.

From the SVMs to the SVMA per ton for a lifetime T of the project

	Technological pessimism path		Technological optimism path	
Discount rate	5%	2%	5%	2%
$SVMA_{T=10}$	73,50	87,25	36,66	43,24
$SVMA_{T=20}$	75,76	104,71	36,54	50,20
$SVMA_{T=30}$	72,26	115,34	35,56	56,96
$SVMA_{T=40}$	68,82	127,50	34,34	64,22

2

What is remarkable is that, even with a high 5% discount rate, the long life projects are not that much penalized if compared with short life projects. They even receive a higher support per ton with a 2% discount rate. This is why the calibration of the guarantees on the SVM allows for recognizing the value of long term investments and pave the way to their recognition as long term assets

Ultimately an agreement about the SVM trajectory and the discount rate will be political in nature. It should be easier that around a price of carbon because a VSM does not hurt existing capital stock and serves as a rule for the organization of a new financial facility supporting new investments. Moreover it could be revised every three to five years in function of new information and of the experience of the incentivizing power of the system.

Box 2: From de-risking low carbon investments to the generation of low carbon assets: a framing note

Different ways of scaling up climate finance have been envisaged over the recent years. The G20 asked the Financial Stability Board (FSB), presided over by Bank of England governor Mark Carney, to investigate the possibility of voluntarily disclosing climate-related financial risks in portfolios. However, although disclosure can incite the financial intermediaries to refrain from investing in fossil-based energies, it is unsure indeed that the funds will be invested in low carbon infrastructures.

To trigger a wave of low carbon investments demands aligning two movements: de-risking of low-carbon investments and redirecting the global savings managed by institutional investors, investment banks, sub-sovereigns, industry and local communities. A prerequisite to do so in the generation of long-term low carbon assets that are secure and liquid enough to attract bond markets with LCIs at low interest rates. The graph below sketches the basic principles to generate such ‘Climate Remediation Assets’.

(i) The European Union and each of its Member State, unilaterally or together with non-EU countries, adopts a SVMA trajectory to calibrate sovereign and sub-sovereign guarantees for low carbon investments in proportion of their expected avoided emissions of GHGs as certified by independent Third-Party auditors.

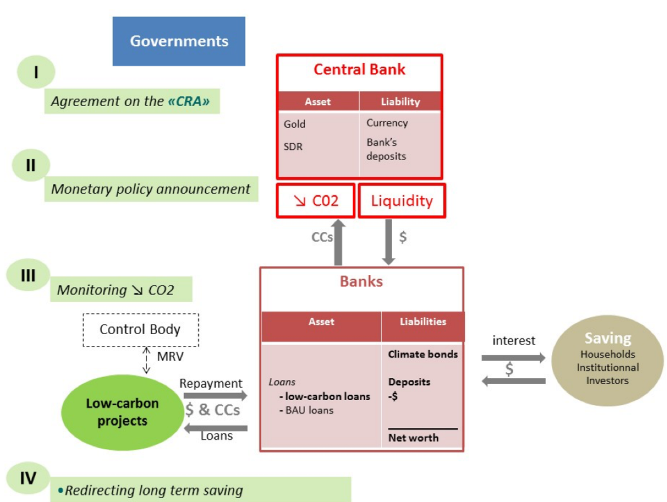
(ii) The loans get through this guarantee can be repaid to the lender (an investment bank for example) either in ‘cash’ if the project is fully successful, or through “carbon remediation assets» that testify effective carbon emission reduction after due control by an independent Third Party.

(iii) Banks or specialized climate funds can use this carbon-based facility to back highly rated climate bonds, in order to attract institutional investors interested in safe and sustainable assets.

(iv) Since public statutory guarantees are given to the CRAs, the Central Banks of each country will accept them as a repayment of the liquidity they give to the commercial, industrial and development banks to fund the LCIs. The CRAs then enter the central bank’s balance sheet.

This is tantamount injecting liquidities into the economy but, contrary to the conventional quantitative easing policies, with low-carbon investments as collateral. The CRAs could then be recognized in interbank payments. In summary, de-risking LCIs and re-directing savings at the needed scale is tantamount to issue a carbon-based money. The central banks buy a service of carbon emission reduction at a price justified by society’s willingness to pay for a better climate. Carbon-based liquidities can be therefore be considered as «equity in the commonwealth». The equity pays dividends in the form of «actual wealth» created by productive low carbon investments and averted emissions in the short term, a stronger resilience of the economy to environmental and financial shocks in the longer term.

The key elements of a climate-friendly financial architecture



A more detailed examination of this mechanism can be found in Hourcade, J-C., Aglietta, M., Perissin-Fabert, B., 2014. Transition to a low-carbon society and sustainable economic recovery, A monetary-based financial device, Concept Note, CIRED-CEPII-CDCclimat-EPE

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