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Climate Change, Low-Carbon Transition and Potential Growth

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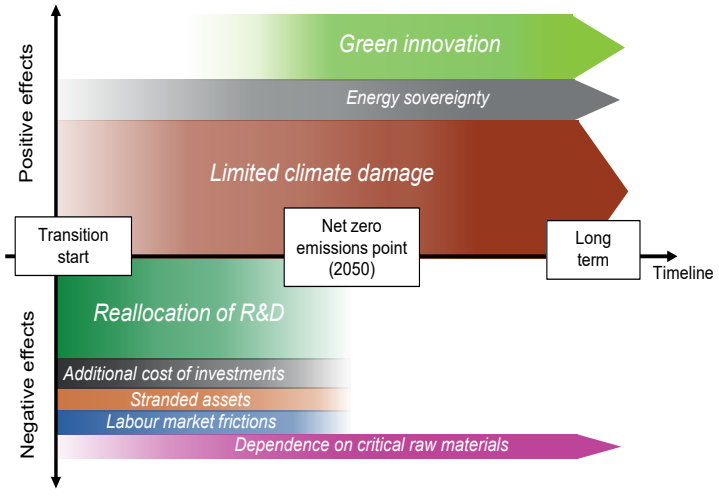
- Potential growth refers to the increase in output that an economy can sustain making full use of its capacities without generating price pressures. This study focuses on variations in potential growth due to climate change and the low-carbon transition. The comparative analysis takes a hypothetical scenario in which there is neither climate change nor transition in order to analyse their effects separately.

- Climate change has a significant negative impact on potential growth, and this impact will only intensify if it is left unchecked. First, climate change represents a risk for the labour supply and worker productivity, which declines in particular during heatwaves. Second, it implies the destruction of assets due to the proliferation of extreme weather events and an investment-disincentivising increase in uncertainty. Third, it risks diverting some production factors and innovation into reconstruction and adaptation to the detriment of more productive areas.

- The low-carbon transition will sharply reduce this negative impact. Yet, it could also trigger a slight downturn in potential growth in the short and medium term, albeit well below the long-term cumulative effects of unchecked climate change. Needs for innovation in low-carbon technologies risk crowding out a proportion of research and development in more productive sectors. Businesses will also need to replace their carbon assets, which could raise production costs. Lastly, job reallocations during the transition phase could temporarily reduce available labour in the event of a skills and geographic mismatch between new green jobs and destroyed brown jobs.

- In the long run, there is the prospect that learning effects, innovation and the spread of technologies across the productive base could cause growth in productivity to return to, if not top the prevalent rate prior to the low-carbon transition (see chart).

Channels of low-carbon transition impact on potential growth



Source: French Treasury (DG Trésor).

How to read this chart: This chart represents the main channels through which the low-carbon transition is projected to impact on potential growth. The height of each block is in proportion to the predicted intensity of the corresponding channel (compared with a counterfactual transition-free scenario for the "limited climate damage" block and with neither transition nor climate change for the other blocks). The colour shading represents how the channels' impacts are expected to gradually diminish or grow.

1. Climate change will reduce potential growth

Climate change will exert significant downward pressure on potential growth by negatively impacting all of its components (labour, capital and total factor productivity). Available impact assessments point out the high cost of climate inaction for the global economy[1] and the French economy.[2]

1.1 Climate change depresses labour supply availability and productivity

Climate change could reduce the labour supply due to extreme weather events and the intensification of pollution[3] and health risks. In the face of sharper temperature swings and pollution peaks, workers could choose or be forced to work fewer hours, thereby decreasing the potential GDP level (see Box 1 for a definition of this concept). Intertemporal (as well as geographic and inter-sector) substitution of working hours could cushion this reduction, but would not always be possible in view of the proliferation and intensification of heatwaves expected in France. The International Labour Organization (ILO) projects that 2.2% of total working hours worldwide will be lost to high temperatures in 2030.[4] Rising temperatures, ecosystem destabilisation and pollution will also drive up morbidity due to the spread of infectious and tropical diseases, thereby increasing the risk of labour force immobilisation. In addition, natural disasters negatively impact on the local labour supply in the short to medium run.

Worker productivity risks falling as a result of across-the-board rising temperatures. The micro-econometric literature and laboratory experiments find a non-linear decreasing relationship between temperature and labour productivity, in terms of both physical work (agriculture and factories) and intellectual work (offices, banks, call centres and schools, due mainly to strain and mental fatigue). Ten extra heatwave days reduce a firm's annual labour productivity by an estimated 0.3%,[5] and this effect grows with the length and intensity of the heatwave. The impact of rising temperatures on labour productivity could reduce French GDP by 0.2% in 2050.[6] Pollution peaks and the spread of disease also risk reducing human capital by altering worker capacities.[7]

The main determinant of labour supply and labour productivity developments due to climate change will reside in the adaptation of workers and businesses. In particular, investments in adaptation to extreme heat will significantly reduce the impact of temperature on mortality and productivity (e.g. sun blinds and shades, thermal insulation, mechanical assistance for workers, the automation of certain tasks and, in some cases, air conditioning). The deployment of such investments will depend mainly on financial, technical and organisational constraints. Nevertheless, certain activities, primarily outdoor work, will not be able to be protected by this type of investment.

(1) Bilal A. and Känzig D. (2026), "The Macroeconomic Impact of Climate Change: Global vs. Local Temperature", *The Quarterly Journal of Economics*. The authors estimate from historical panel data that a 1°C rise in the global temperature will cause a 20% long-run reduction in world GDP in the absence of structural changes to adaptation behaviour.

(2) NGFS (2023), "NGFS Climate Scenarios for Central Banks and supervisors - Phase IV". The Network for Greening the Financial System (NGFS) estimates that climate inaction could cost France more than 7% of its GDP by 2050, compared with above 3% in an orderly transition scenario. The NGFS is working on updating these figures in the near future.

(3) Climate change exacerbates certain forms of pollution. For example, heatwaves drive the formation of ground-level ozone, while smoke from drought-induced forest fires impairs air quality.

(4) Kjellström T., Maître N., Saget C., Otto M. and Karimova T. (2019), "Working on a warmer planet: The impact of heat stress on labour productivity and decent work", ILO.

(5) Costa H., Franco G., Unsal F., Mudigonda S. and Caldas M. P. (2024), "The heat is on: Heat stress, productivity and adaptation among firms", OECD, *Economics Department Worling Papers*, No. 1828.

(6) Szewczyk W., Mongelli I. and Ciscas J-C. (2021), "Heat stress, labour productivity and adaptation in Europe-a regional and occupational analysis", *Environmental Research Letters*, 16(10).

(7) Baratgin L., Eupherte A. and Taconet N. (2026), "Beyond Health Impacts: the Heavy Economic Toll of Air Pollution", French Treasury, *Trésor-Economics*, No. 380.

Lastly, climate change implies a change in migration flows, with as yet an unclear impact on GDP and potential growth. Climate change could cause an increase[8] in migration flows of uncertain composition, since income strongly conditions the coping abilities and destination choices of populations considering migration. Although the poorest populations in the countries most exposed are the most vulnerable to climate change and therefore have the greatest incentive to migrate, they have less means to do so. Migration-incentivising institutional factors (such as political stability and local adaptation policies) can also be influenced by climate change. Furthermore, although migration flows are associated with economic gains for destination economies in the long run, they can generate slight labour market frictions in the short run.[9]

Box 1: Definitions of the potential growth and productivity concepts and the chosen counterfactual scenario

Potential GDP is defined as the level of output that an economy can sustain making full use of its capacities without generating inflationary pressures.[a] Under this approach, potential GDP and its growth are functions of:

- Available labour, which itself depends on the working-age population, trend hours worked per person and structural unemployment, which persists at equilibrium. A qualitative factor can also be included in this definition with a human capital level indicator representing all the skills, talents, qualifications and experience accumulated by individuals.
- Available capital stock, which is made up of all the physical and intangible assets used in the production process (buildings, machines, software, patents, infrastructures, etc.).
- Total factor productivity (TFP) is the portion of growth not explained by growth in labour and capital. TFP reflects the quality of the allocation of labour and capital, the effects of technological progress, the spread of innovation in the productive systems, business dynamism (entry and exit of firms with different productivity rates) and the co-benefits of public investment (in infrastructures).

Table 1 presents a summary of the different channels through which climate change and the low-carbon transition impact on potential growth in France.

The counterfactual scenario used in this document is based on a theoretical trajectory with neither low-carbon transition nor climate change.

a. Herlin A. and Gatier A. (2017),"Potential Growth in France", French Treasury, *Trésor-Economics*, No. 206.

(8) Yet, there is little agreement on this subject in the literature and a not-inconsiderable proportion of the empirical studies find non-significant, if not negative effects of climate change on migration. See Beine M. and Jeusette L. (2021), "A meta-analysis of the literature on climate change and migration", *Journal of Demographic Economics*, 87(3), 293-344.

(9) Batut C., Gantois T. and Lavallée J. (2024), "Intra-EU Mobility of Persons", French Treasury, *Trésor-Economics*, No. 337.

Table 1: Summary of the channels through which climate change and the low-carbon transition impact on potential growth in France

Channel/ transmission factor	Impact on potential...	Climate change		Low-carbon transition	
		Mechanism	Channel intensity	Mechanism	Channel intensity
Labour	Level	Chronic reduction in hourly productivity	– –	Skills mismatches between jobs destroyed and created	–
		Higher morbidity due to the increase in pandemics	–	Geographic mismatch between jobs destroyed and created	–
		Reduction in human capital	–	Lack of attractiveness of green jobs	–
		Climate migration	?	Improvement in working conditions	+
		Reduction in the number of days able to be worked	–		
Capital	Growth	Increase in volatility, uncertainty and financial vulnerability: drop in productive investment	–	Loss of value in underlying financial assets	–
				Crowding-out effect of low-carbon investment on other investments	–
	Level	Destruction of capital stock	– –	Underuse of productive capital	–
		Underuse of productive capital	–	Cost of installing low-carbon assets	–
		Accelerated obsolescence of capital stock	–	Accelerated obsolescence of capital stock	–
		Loss of natural capital	–	Renewal of productive capital	+
Total factor productivity	Growth	Creative destruction process	?	Redirection of R&D to decarbonisation	– –
		Diversion of production factors and R&D into resilience, reconstruction and adaptation	– –	Green innovations	++
				Reallocation of business to low-carbon firms	?
	Level	Loss of competitiveness due to integration into global value chains	– –	Increase in production costs	– –
				Dependence on fossil fuels	+
				Dependence on critical raw materials	–

How to read this table: Table 1 sums up the identified channels through which climate affects potential GDP level and growth. Signs "–" and "+" indicate the direction of the predicted effect (negative or positive) and the repetition of a sign indicates the magnitude of the effect (a single sign for a moderate impact), A "?" sign indicates an uncertain effect.

1.2 The increase in the frequency and magnitude of extreme weather is causing premature degradation of the capital stock

Climate change is characterised by both an intensification and an increase in the frequency of extreme weather events, which directly destroy capital (goods and infrastructures). The Caisse Centrale de Réassurance (a French public-sector reinsurance company) used IPCC[10] scenarios to estimate the increase in average climate-induced loss experience[11] in France by 2050: it could rise by 27% to 62% due to climate change alone and even by 47% to 85% when factoring in growth in the population and the number of businesses compared with the current situation.[12] The number one factor in this is the expansion of flood-prone areas due to climate change, since floods are the main cause of the damage considered. The economic impacts of extreme weather events in urban centres, which are already subject to greater risks due to heat islands, are exacerbated by the fact that they concentrate economic activity (consumption and service production). The French overseas territories are also highly exposed to cyclones, whose causal effect on economic activity persists at an estimated -0.4 percentage points of GDP twenty years after they hit. Lastly, 55% of mainland France is now prone to forest fires (average over the 2016-2025 period) as opposed to 21% over the 1961-1990 period.[13]

Existing infrastructures in certain sectors, such as those in seasonal tourism, could depreciate prematurely.[14] Soil destabilisation, due in particular to clay shrink-swell, directly threatens the stability and quality of the industrial and building stock.

This deterioration in the capital stock will raise the cost of investment by means of two channels. For businesses, the risk of asset deterioration is associated with a higher rate of depreciation, which raises the cost of the capital. The expected breakeven point for investment projects therefore also increases, penalising the aggregate investment. The loss of asset value could reduce the capacity of banking and financial institutions to grant loans.[15] Businesses' financial constraints would then tighten and productive investment would fall, even as investment needs for adaptation and resilience grew. In addition, the greater environmental uncertainty would change investors' behaviour and strengthen aggregate risk aversion, which could drive up insurance premiums and increase the cost of credit, thereby further degenerating business financing conditions.

The natural capital approach (including water, land – counting minerals and resources –, air and ecosystems) demonstrates that climate change results in capital erosion. Economic studies do not generally mention natural capital as a production factor, since it is very hard to model it and isolate its effect. Yet, it plays a key role in productive processes: the economic value of 17 ecosystem services provided by natural capital for the entire biosphere was estimated at more than twice global GDP in 2014,[16] and the cost of erosion due to land and ecosystem degradation has been estimated at 5% of global GDP per year.

(10) The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for objectively assessing scientific research on climate change.
(11) Loss experience, an insurance term, is the monetary value of claims for insured losses.
(12) Caisse Centrale de Réassurance (2023), "Étude sur les conséquences du changement climatique sur le coût des catastrophes naturelles en France à horizon 2050", L'Essentiel by CCR (in French only).
(13) High Council on Climate (2026), "Dangers climatiques: la France face à ses responsabilités", annual report (in French only).
(14) The mountain economy has been hit by shrinking snow coverage, while the sustainability of summer tourism on the Mediterranean seaboard is endangered by the intensification of heatwaves and water scarcity.
(15) The loss of value in the assets underlying the depreciated capital could force them to increase their provisions, which would reduce loans granted.
(16) Costanza R., de Groot R., Sutton P., van der Ploeg S., Anderson S. J., Kubiszewski I., Forber S. and Turner R. K. (2014), "Global Environmental Change", *Nature*, Vol 26. P 152-158. See also Bouchet V., Bourcet C., Cécillon E. and Lavaud S. (2021), "Economic Assessments of Services Provided by Biodiversity", French Treasury, *Trésor-Economics,* No. 294 ; Bastit F. Grémillet A. and Pasteau E. (2026), "Forests and the Wood Industry: The Cornerstones of the Green Transition and Economic Resilience", French Treasury, *Trésor-Economics*, No. 399.

1.3 Some production factors will be channelled into reconstruction and climate change adaptation needs, resulting in a loss of total factor productivity

Potential growth and the economy's productivity depend not only on firm-level productivity gains, but also on the allocation of production factors, which is affected by economic shocks. Climate change redirects a portion of resources to adaptation and to preventing and reconstructing climate damage. The need for this investment could create a crowding-out effect by diverting part of the production factors supporting potential growth. The hypothesis of creative destruction in disaster areas, whereby natural disasters are supposed to provide opportunities to upgrade the capital stock to higher performance technologies, remains controversial especially in the light of the impending increase in the frequency and intensity of these extreme weather events.

The economic repercussions of climate change can also drive a reconfiguration of the value chains. The proliferation and intensification of natural disasters worldwide could immobilise transport, suppliers and production units as well as increase the frequency of bottlenecks.[17] In France, these extreme climate events could encourage businesses to turn to foreign components. At the macroeconomic level, these two transmission channels imply an increase in the costs of inputs and a drop in productivity due to the reconfiguration of production systems. Nevertheless, logistical chain diversification does guarantee against supply disruptions caused by local disasters.

2. Although the transition could trigger a slight downturn in potential growth in the short and medium term, it will have positive effects on potential growth in the long term, primarily in terms of the damage prevented

From a macroeconomic point of view, the low-carbon transition depends largely on the replacement of fossil fuels with low-carbon energies, energy efficiency gains and energy sufficiency.[18] The full phase-out of fossil fuels will therefore require technological progress to be channelled into green technologies, additional investments (in decarbonisation and energy efficiency) and behavioural changes.

2.1 The transition will call for low-carbon innovations with a short-term risk of crowding out more productive innovations, but with the ability to support growth in the long term

The low-carbon transition measures could have a slight negative effect on potential growth in the short and medium term, albeit well below the long-term cumulative impact of unchecked climate change. The low-carbon transition calls for innovation in energy efficiency to reduce carbon emissions from energy consumption. Yet, research and development (R&D) is a priori a finite resource: the share of R&D expenditure in GDP in France has remained stable at around 2% since the 1990s, and it would be hard to adjust the number of researchers in the short and medium term. So, over this period, the main means of adjustment is the allocation of research among the different sectors. An increase in R&D expenditure on decarbonisation could therefore be to the detriment of research improving economic growth.

Economists use endogenous growth models to quantify this slowdown. These models are stylised representations of the economy in which the long-run growth rate is determined by the model's variables and internal dynamics, including technological progress

(17) Schleypen J., Dasgupta S., Borsky S., Jury M., Ščasný M. and Bezhanishvili L. (2019), "D2.4 Impacts on Industry, Energy, Services, and Trade", Deliverable of the H2020 COACCH project.

(18) Pisani-Ferry J. and Mahfouz S. (2023), "Les incidences économiques de l'action pour le climat – Rapport de synthèse", France Stratégie (English summary here). For quantitative assessments conducted for France on the impact of the low-carbon transition on GDP covering these different factors, see French Treasury (2025), "The economic challenges of the transition to carbon neutrality", Chapter 2 ; and French Government (2026), "Rapport d'accompagnement de la Stratégie nationale bas-carbone n° 3", Chapter 3 (in French only).

made by R&D. For the low-carbon transition in particular, these models simulate R&D expenditure allocation among different sectors (e.g. productive and energy-saving R&D), which is endogenous, based on their relative profitability. The Mouette model, for example, was developed by the French Treasury (DG Trésor) to evaluate the extent of the productivity slowdown due to the reallocation of R&D (see Box 2).

The Mouette model's findings estimate the loss of annual growth in labour productivity in France due to an 85% reduction in the use of fossil fuels by 2050 at around 0.15 percentage points on average. It models the energy transition measures by means of an increase in carbon tax and the introduction of an R&D subsidy to reduce energy-related carbon emissions. This model demonstrates that, by increasing the price of carbon, transition policies increase the relative profitability of energy-saving R&D expenditure compared with productive R&D expenditure. As the price of fossil fuels increases, it becomes more profitable to develop technologies to reduce fossil fuel consumption. This increase in the carbon price also leads households and businesses to replace fossil fuels with low-carbon energy in their consumption. In this model, when the transition is complete, carbon taxation stops increasing and the rates of growth in technological progress in the different areas gradually return to their initial level (see Chart 1).

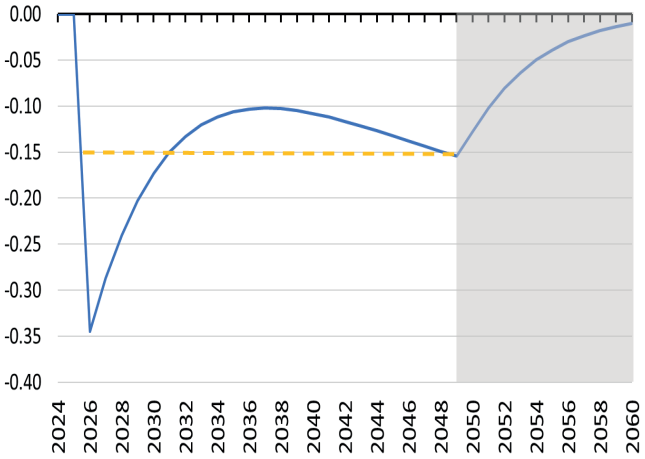
Box 2: Presentation of the Mouette model (2025)[a]

The Mouette model (Model Used to Evaluate Energy Transition Trajectories) is an extension of the model developed in an article by Henriet et al. (2014).[b] The French economy is modelled in the form of a small open economy[c] producing a generic good, which can be consumed or invested. The model includes the use of fossil fuels and low-carbon energies, by both households and businesses, as well as three types of technological progress in terms of labour efficiency, fossil fuel efficiency and low-carbon energy efficiency respectively. The economy's total R&D expenditure is a proportion of output set by the modeller. Nevertheless, the allocation of this amount among the abovementioned three R&D sectors, and therefore growth in the three corresponding types of technological progress, is endogenous: an increase in fossil fuel price (due, for example, to an increase in environmental taxation) induces both an increase in R&D expenditure to save fossil fuels (now more expensive) to the detriment of R&D to increase labour productivity, and the replacement of fossil fuels with low-carbon energy.

This model makes a trade-off between economic growth and energy transition. A high level of R&D expenditure to raise labour productivity (e.g. by improving information and communication technologies) ensures a high growth rate for the economy, but generates less growth in energy efficiency gains, resulting in higher carbon emissions. Conversely, energy-saving R&D expenditure reduces carbon emissions, but can slow economic growth. The model does not consider the effects of climate change.

a. A detailed presentation of the model is available in Baratte G., Cervoni M., Derouen C., Girard P. L. and Grept R. (2026), "Changement climatique, Transition écologique et croissance potentielle", French Treasury, *Working Paper*, No. 2026/2 (in French only).
b. Henriet F., Maggiar N. and Schubert K. (2014), "A Stylized Energy-Economy Model for France", *The Energy Journal*.
c. In the model used, France engages in international trade, but is assumed to be small enough so as not to influence foreign prices or global demand for its output. The international environment is assumed to be exogenous.

Chart 1: Impact on the labour productivity growth rate of an increase in carbon taxation and the introduction of an R&D subsidy, together associated with an 85% reduction in fossil fuel consumption by 2050



Source: Results of the 2026 Mouette model, French Treasury.

How to read this chart: The impact is measured as a deviation from a baseline with neither transition nor climate change.

Note: The simulated scenario corresponds to a 15% annual increase in carbon taxation through to 2050 and the introduction of a set 20% subsidy for energy-saving R&D. These parameters reduce fossil fuel consumption by 85% by 2050, in particular by improving the profitability of energy-saving R&D expenditure compared with other sectors. Annual growth in labour productivity slows by 0.15 percentage points on average through to 2050. The peak in 2026 is due to the size of the initial shock and the introduction of the subsidy in particular. Subsequently, the simulated technological progress growth rate deviations narrow compared with the baseline scenario. Therefore, only the average deviation in technological progress compared with the baseline scenario during the transition phase should be interpreted.

A number of mechanisms, not modelled, could mitigate this effect on productivity. First, the extent of the productivity slowdown could be reduced by sharing the innovation effort among countries. In particular, if the transition is coordinated and the French economy benefits from energy efficiency innovations developed abroad, then less R&D expenditure would be required for the French economy's decarbonisation and there would be less crowding out of productive R&D. Second, positive externalities could be observed between the different R&D sectors, which would also reduce the crowding-out effect on productive R&D.[19] Third, although the share of R&D expenditure in GDP has remained relatively steady in France for the last 30 years, the needs for research focusing on the low-carbon transition could well drive up this share in the medium run. This would reduce costs in terms of potential growth. Lastly, a change in energy consumption could come from behavioural changes made by economic players saving more energy[20] due to public policies or a change in preferences.

In the long run, the low-carbon transition is expected to trigger "green innovations", whose capacity to generate productivity gains is uncertain. This is known as the Porter Hypothesis. In its weak version, corroborated by the empirical literature, mitigation policies encourage green innovation. Green innovation would also bring widespread positive spillovers: "green" technology patents would generate greater knowledge spillovers for the rest of the economy than the "brown" technology patents they replaced.[21] However, there is some debate in the literature over the strong Porter Hypothesis, which holds that these innovations would generate productivity gains compared with a transition-free scenario (see Section 2.3 below).

All in all, although growth in firm-level productivity decreases in the short run following the introduction of stricter environmental policies (see Section 2.2 below), this slowdown could be offset in the long run by a significant increase in the number of patents filed, the spread of new technologies across the means of production and the upgrading of the capital stock.

2.2 The transition will force businesses to replace their carbon equipment, which could induce transformative changes to their means of production, if not compel them to delay certain productive investments

Transition policies are expected to have a negative impact on firm-level productivity in the short term due to an increase in production costs and the reorganisation of the production system. Businesses may well be forced to allocate part of their production factors to the decarbonisation of their productive process and energy

(19) See Nemet G. F. (2012), "Inter-technology knowledge spillovers for energy technologies", *Energy Economics*, Vol. 34, pp. 1259-1270, who studies inter-technology knowledge flows for energy patents and suggests that energy research is applied extensively.
(20) ADEME Opinion (2025), "Vers une économie de la sobriété" (in French only).
(21) Dechezleprêtre A., Martin R. and Mohnen M. (2017), "Knowledge spillovers from clean and dirty technologies: A patent citation analysis", Grantham Research Institute on Climate Change and the Environment, *Working Paper*, No. 135.

efficiency in order to comply with new climate standards and minimise the impact of the carbon price increase. Consequently, given the same amount of available labour and capital, business output could drop. The need to engage in green investments could also cause productive investments to be postponed. This effect would spread from today's high-carbon sectors to other downstream sectors to which they would pass on the cost increase. A number of empirical studies observe a short-term downturn in firms' total factor productivity (defined in Box 1) following a tightening of climate policy[22] or an increase in energy prices,[23] which could be due to a downward adjustment in the utilisation of their production capacities.

Drawing on a macroeconomic model capturing the effects on total factor productivity of the reconfiguration of the capital stock induced by the low-carbon transition, the Banque de France[24] finds a slowdown that could reach an annual average of 0.3 percentage points by 2030. This is in principle an upper bound, which does not factor in learning effects,[25] for example. Similarly, the French Treasury has developed a partial equilibrium model to analyse the effects of decarbonisation investments on productivity (see Box 3) and finds an estimated annual average drop in growth in France of 0.04 percentage points during the transition phase.

The risk of part of the productive capital becoming obsolete or stranded due to the transition appears to be limited, provided that the transition is orderly and predictable enough for agents to be able to adjust their behaviour. If the transition is abrupt, unpredictable or happens when green technologies are not sufficiently developed, the carbon-intensive capital would become obsolete before its theoretical depreciation, thereby reducing the capital stock.[26] Conversely, the risks of a downturn in aggregate investment are reduced by the definition of a shared, planned and credible transition pathway vision.[27] The risk of stranding is minimised by a carbon budget decarbonisation approach[28] (with a cap on greenhouse gas emissions over a given period, such as the cap contained in the Third National Low-Carbon Strategy – SNBC3), which increases the transparency of the transition.

However, an increase in productivity could be observed in the short term in firms closest to the technological frontier.[29] In particular, these firms can in principle more easily adjust their use of energy and labour in their production process. In addition, green technology costs should decrease as the transition advances. This applies in particular to electricity generation, where renewable technologies (especially solar power) now cost less on average than their carbon alternatives. Lastly, the dynamics of entries by low-carbon productive firms and exits by high-emission senescent firms should improve the allocation of labour and capital, which would support aggregate productivity.

(22) See Benatti N., Groiss M., Kelly P. and Lopez-Garcia P. (2024), "The impact of environmental regulation on clean innovation: are there crowding out effects?", *ECB WP Series,* No. 2946 or Dechezleprêtre A. and Sato M. (2017), "The Impacts of Environmental Regulations on Competitiveness", R*eview of Environmental Economics and Policy*, Vol. 11 2, pp. 183-206. Note that Alla A. (2022), "European Union's emissions trading system and productivity: firm-level evidence for France, Italy and Spain", French Treasury, *Working Paper*, No. 2022/3 shows that the European emissions trading system introduced in 2005 was not detrimental to French firms' total factor productivity.

(23) See André C., Costa H., Demmou L. and Franco G. (2023), "Rising energy prices and productivity: short-run pain, long-term gain?",*OECD Economics Department Working Paper*, No. 1755, and Marin G. and Vona F. (2021), "The impact of energy prices on socioeconomic and environmental performance: evidence from the French manufacturing establishments, 1997-2015", *European Economic Review.*

(24) Henriet F., Kalantzis Y., Lemoine M., Lisack N. and Turunen H. (2025), "Bridging the Gap in Macroeconomic Analysis of the Energy Transition: Combining Medium- and Long-Term Approaches", Banque de France, *Working Paper*, No. 1000. This shock is then fed into their FR-BDF macro-econometric model to evaluate the effects on the French economy.

(25) Learning effects refer to the fact that the more a firm produces over time, the more it acquires experience and becomes efficient. In the case of the replacement of carbon equipment with low-carbon equipment, after a certain amount of time, staff have a better command of the new equipment, the organisation improves, errors are reduced and production techniques are optimised.

(26) Parker M. (2023), "How climate change affects potential output", European Central Bank, *Economic Bulletin*, Issue 6/2023.

(27) See, for example, the International Energy Agency (IEA) (2017), "Climate Policy Uncertainty and Investment Risk".

(28) Abbas R., Carnot N., Lequien M., Quartier-La-Tente A. and Roux S. (2024), "On the way to net zero. But which way?", INSEE, *Working Paper,* 2024-11.

(29) Albrizio S., Kozluk T. and Zipperer V. (2017), "Environmental policies and productivity growth: Evidence across industries and firms", *Journal of Environmental Economics and Management.*

Box 3: Model to compute the additional cost of decarbonisation investments

The French Treasury has developed a model to compute the downturn in productivity growth due to the additional cost of investments required for the decarbonisation of the means of production and the induced changes. The analysis is based on an aggregate production function. A negative productivity shock is calculated to obtain an increase in the aggregate capital stock consistent with the additional investments in decarbonisation – net of disinvestment in high-emission capital and variations in other investments concerned by the low-carbon transition – for a given level of output, labour and productive investment. The investment schedules used are consistent with the latest SNBC3 targets. The loss of annual labour productivity growth is predicted to reach its height around 2030 before dipping back down and becoming insignificant as of 2040. The loss is estimated at an average 0.04 percentage points per year by 2050.

This model can be used for macroeconomic evaluations of the low-carbon transition computed using large models (such as ThreeME[a]). These exercises generally juxtapose a carbon price shock (to which support measures can be added) with a shock made up of additional investments (low-carbon, net of disinvestment in high-emission capital and financed), calibrated based on microeconomic studies. Investment shocks are usually positive demand shocks whose effects are depleted in the medium to long run by a dual crowding-out effect channelling through prices and imports. However, the models used cannot capture the effects on productivity beyond the sector reconfiguration effect. The use of a productivity shock calibrated off-model, albeit an imperfect solution, enables this transmission channel to be evaluated.

a. See French Government (2026), "Rapport d'accompagnement de la Stratégie nationale bas-carbone n° 3", Chapter 3 (in French only).

2.3 Job reallocations could create temporary job supply and demand imbalances

Green transition policies call for a major structural change to the economy liable to give rise to job reallocations. However, the jobs concerned are estimated to represent a low percentage of total employment in France. A classification developed by the French Treasury[30] finds that brown jobs (all occupations in high-emission activities and some occupations in green and white activities) accounted for 9.2% of total French employment in 2021, but not all of them are at high risk from the transition. Just 3.0% of jobs can be considered to be particularly exposed. These are brown occupations in polluting activities concentrated in sectors using fossil fuel products (refining, automotive industry, metallurgy, and road and air transport). Brown occupations in green and white activities represented only 1.0% of wage employment in 2021 and they could see their tasks and skills evolving more than a reduction in their staff numbers. Green and greening occupations in brown activities (0.9% of wage employment in 2021) and white occupations in brown activities (4.3% of wage employment) should have possibilities to transition to other activities. Moreover, high same-sector firm heterogeneity is expected to give rise to more in-sector than inter-sector reallocations.[31]

These direct job reallocations driven by transition policies should remain modest compared with total job creations and destructions, representing approximately 20% of total employment per year according to French Council of Economic Analysis estimates.[32] This impact, which would depend on socioeconomic conditions and the type of climate policies (positive net effect in the case of pricing policies and negative net effect in the case of regulatory policies), is expected to disappear in the long run.[33]

The skills mismatch between jobs created by the green transition and available workers could put a brake on job reallocation, although the risk is hard to estimate. Green jobs are generally more skills-intensive than

(30) French Treasury (2025), op. cit.
(31) Fontaine F., Ollivier H., Saussay A. and Schubert K. (2023), "Energy transition: should we fear for jobs?", French Council of Economic Analysis, Note No. 80.
(32) Fontaine F. et al. (2023), op. cit.
(33) Mohommad A. (2021), "Employment effects of environmental policies – evidence from firm-level data", IMF, *Working Papers,* No. 21/140.

white jobs.[34] They can demand both a broader and deeper skillset, with strong heterogeneities depending on the occupations and sectors.

Low worker mobility could also constrain the reallocation of labour at local level in the event of limited geographic overlap between declining brown jobs and emerging green jobs.[35] In France, the weight in employment of the highest greenhouse gas emission sectors varies sharply across geographic areas. Green activities, on the other hand, are homogeneously distributed across the country.

Moreover, if green transition policies are well designed, they could generate co-benefits with positive effects on the labour supply and worker productivity and health in addition to their contribution to containing the intensification of climate change and its harmful effects (extreme temperatures, air pollution, diseases, etc.). For example, by improving air quality, carbon neutrality has the potential to prevent premature deaths caused by air pollution: in the Fit for 55 scenarios, the European Commission estimates the reduction in premature mortality at 17,000 untimely deaths per year in France.[36]

(34) French Treasury (2025), op. cit.
(35) Saussay A., Sato M., Vona F. and O'Kane L. (2022), "Who's fit for the low-carbon transition? Emerging skills and wage gaps in job ad data", Centre for Climate Change Economics and Policy, *Working Paper* 30645.
(36) European Commission (2021), "Policy scenarios for delivering the European Green Deal" .

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