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Economic research

The importance of the link between climate change and population for economic development

This articles proposes a review of the literature on the effects of climate change on population and economic growth, especially in developing countries. Climate change affects mortality and living conditions via the direct impacts of extreme temperatures and via indirect impacts mediated by the environment and social systems. Demographic factors contribute to growth through various channels, including capital accumulation over individuals' life cycle, investment in education, an increase in income per capita in countries where the fertility transition has occurred, and their impact on labour productivity. However, the macroeconomic importance of these factors remains subject to debate. Future research should therefore improve the quantification and integration of population effects in models assessing the macroeconomic impact of climate change, and take better account of climate policies.

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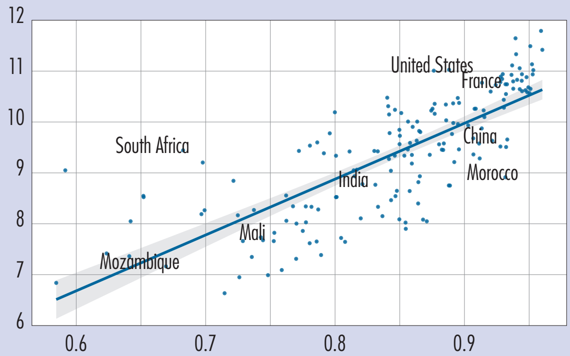
JEL codes
G56, I15, J24,
Q51, Q54

Over **150,000**
annual number of deaths directly linked to the anthropogenic climate change of the last 30 years

1 in **9** deaths
worldwide is linked to air pollution

9.1%
increase in labour productivity associated with a rise of 0.1 in the rate of survival of adults aged 15 to 60.

Correlation between the survival rate and productivity (2018)
(x-axis: survival rate for the 15-60 age group;
y-axis: log GDP per capita)



Sources: World Bank data (World Development Indicators), author's calculations based on Bloom et al. (2019).

1 The effects of climate change on population are particularly significant in developing countries

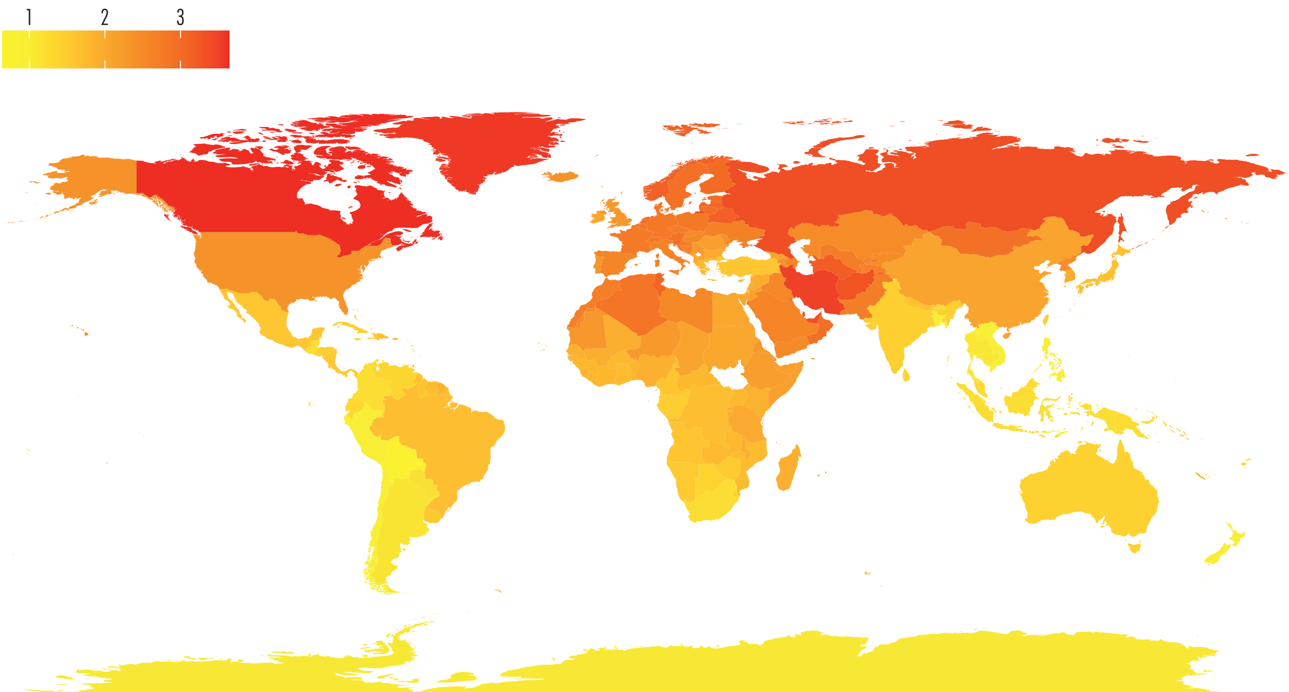
While the theoretical study of the impact of demographics on the environment dates back to Thomas Malthus in the 18th century, scientists have gradually produced evidence of a close but more complex relationship between climate change and demographic factors. Indeed, a close circular relationship exists between climate change and population, which also depends on the level of economic development. Levels of greenhouse gas emissions are not directly correlated to demographic weight or to rates of demographic growth, and developed countries' share of emissions is systematically higher than their share of the global population.[1] In addition, developing countries are particularly vulnerable to the global phenomenon of climate change. In these countries, the main concern related to the link between climate and demographic factors is about the impact of climate change on the population, which can in turn affect economic growth.

The literature in environmental economics identifies and quantifies several channels through which climate change affects populations' living conditions: direct effects and indirect effects mediated by the environment or social systems.

Direct effects of extreme temperatures

The effects of temperature on demographics have been studied in depth and are widely recognised by global institutions.[2] According to the World Health Organization (WHO), for example, the anthropogenic climate change of the last 30 years already claims more than **150,000 lives per year**.

C1 Average increase in global land temperatures since 1960
(°C per century)



Source: Berkeley Earth.
Interpretation: Land temperatures in France have risen at an average rate of 2.77°C per century between 1960 and the recent period.

1 In 2015, the United States accounted for 15.6% of global emissions and 4.4% of the global population. France accounted for 0.97% and 0.91% respectively, and China for 29.3% and 18.6%. Note that these measures of emissions are based on national output and not national consumption. Therefore, they do not include imported emissions.

2 For a review of the literature, see *Climate Change 2007: Synthesis Report*, the fourth assessment report of the International Panel on Climate Change (IPCC), and *A Human Health Perspective on Climate Change*, the 2010 report of the National Institute of Environmental Health Sciences (NIEHS).

A large portion of the literature in environmental economics focuses on the impacts of extreme temperatures, as illustrated by the literature reviews published by Dell et al. (2014) and Deschenes (2014). Many of these studies use a panel-based approach and historical data on temperature changes to show that extreme temperatures have a significant effect on mortality. In the United States, one additional day of hot weather increases the annual rate of mortality by 0.11%, with children and the elderly the most exposed (Deschenes and Greenstone, 2011).

However, this literature focuses mainly on rich countries, and the effects may differ markedly in developing countries. For example, the impact of extreme temperatures on the mortality rate is estimated to be up to 20 times greater in India than in the United States.[3] It is also found to be concentrated mainly in rural areas, suggesting that urban installations play a protective role (Burgess et al., 2017).

Although panel estimates suggest that climate has substantial effects on human health, there are three limitations to using them in projections: (i) the estimations use historical variations in temperature and the validity of the estimates may be questionable in a setting with accelerating climate warming to well over 3°C per century (see Chart 1); (ii) extrapolations are biased in the case of convex costs[4] (additional costs generated by increasingly extreme temperatures); and (iii) models that do not take account of climate change adaptation behaviours lead to inaccurate long-term forecasts.

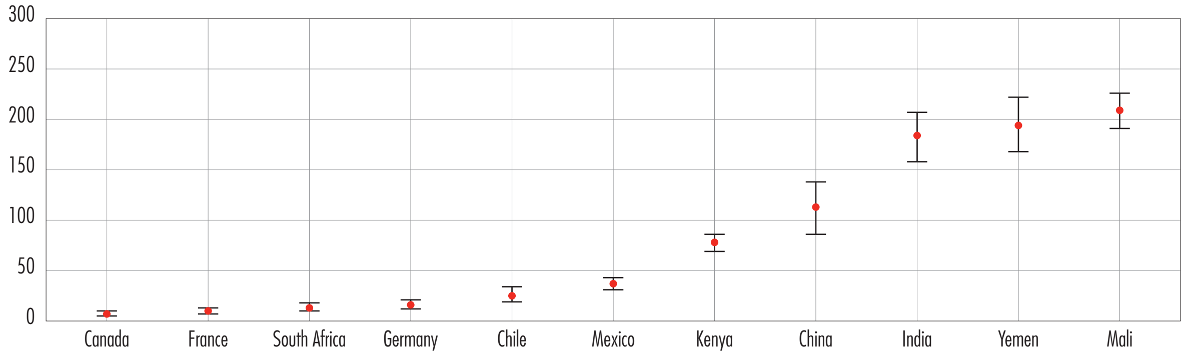
Indirect effects mediated by the environment or social systems

Climate change can affect population mortality or morbidity indirectly by modifying environmental conditions. The main transmission channels are:

• **An increase in air pollution**: a rise in emissions, combined with factors such as climate change, leads to an increase in the concentration of ozone and particles in the lower atmosphere. According to the WHO, air pollution is already responsible for **1 in 9 deaths** worldwide, as well as causing cancers, and respiratory and cardiovascular diseases. Global regions are heterogeneously exposed (see Chart 2). Indoor air pollution caused 3.8 million premature deaths in 2016,[5] whereas outdoor air pollution caused 4.2 million deaths

C2 Impact of air pollution on mortality in 2016

(per 100,000 inhabitants)



Source: World Health Organization (WHO), Global Health Observatory.
Interpretation: The estimated impact of air pollution on mortality in Mexico was 37 deaths per 100,000 inhabitants in 2016.
Note: Estimates (points) are shown with confidence intervals.

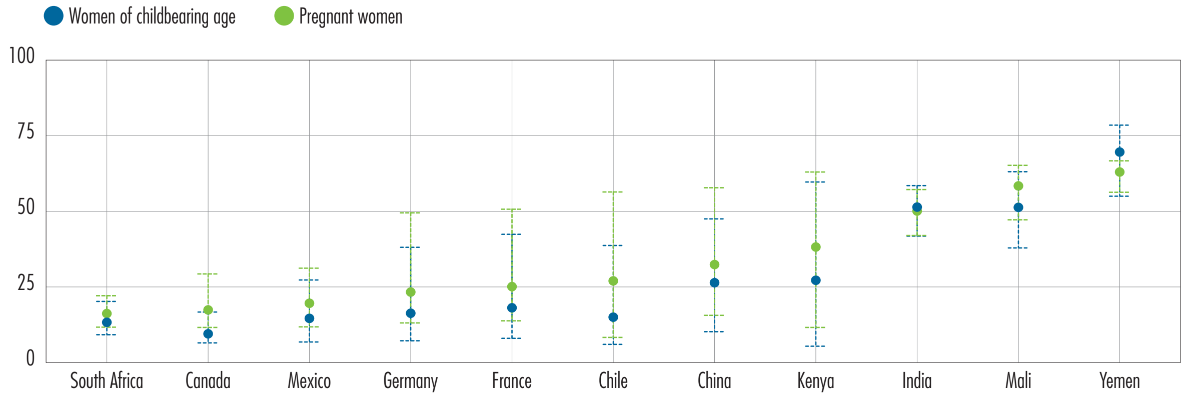
3 Change in the mortality rate in response to an additional day with temperatures above 35°C relative to a day in the range 21-23°C; coefficients estimated over the period 1957-2000 (+0.74 percentage point for India and +0.03 percentage point for the United States).

4 According to the historical data studied by Dell et al. (2012), annual temperatures per country have rarely deviated by more than 1°C from their long-term average (on average, once every 15 years). However, estimates for the probable temperature rise by 2100 are in the range 1.8-3.1°C, and even as high as 7°C at the top end of the IPCC's estimates. Assuming – as is plausible – that climate costs are convex, this raises doubts as to the validity of extrapolations from reduced linear forms. The estimators obtained under these conditions would be a lower limit.

5 World Health Organization (WHO), Global Health Observatory.

C3 Prevalence of anaemia in women in 2016

(%)



Source: World Health Organization (WHO), Global Health Observatory.
Interpretation: According to WHO estimates, 26.4% of women of childbearing age and 32.4% of pregnant women were suffering from anaemia in China in 2016.
Note: Estimates (points) are shown with confidence intervals.

and is expected to cause between 6 million and 9 million per year by 2060 (Organisation for Economic Co-operation and Development – OECD, 2016), with the effects mainly concentrated in densely populated areas (India and China) and in regions with an ageing population (China, Eastern Europe).

- **A surge in vector-borne, food-borne and water-borne infectious diseases:**

  – The consequences of climate change for infectious diseases include the emergence of new diseases, an increase in the prevalence and severity of existing diseases and the more rapid circulation of pathogens (Altizer et al., 2013). Higher temperatures also appear to increase antibiotic resistance (Rodríguez-Verdugo et al., 2020).

  – Malaria is the most deadly vector-borne disease. This tropical illness is extremely sensitive to the climate and is a significant burden to public health in Africa.[6] Children under five are the most at-risk from the disease (accounting for 67% of the 405,000 deaths recorded in 2018).[7] Deforestation and rapid population growth are also aggravating factors.

Climate change has indirect effects on human health via social systems and behaviours (food systems, human migration, distribution of wealth). Climate shocks in early life or *in utero* can affect long-term well-being for biological reasons, but also due to parental behaviours (Wilde et al., 2017). For example, anaemia is one of the main nutritional problems in pregnant women, according to the WHO, especially in developing countries (see Chart 3). It affects maternal morbidity and mortality, as well as infant health. Climate change may increase the risk of anaemia (by reducing the nutritional quality of harvests, increasing parasitic infections and undermining food systems) heterogeneously across countries and individuals (Smith et al., 2017). Children and women of childbearing age are the most at-risk groups (59% of the global total are exposed), especially in South and East Asia, and in North and East Africa.

2 The importance of demographics and quality of life for economic growth

Demographics, and especially changes in mortality and fertility, have major implications for economic development. Quality of life is also a significant determinant of growth. Their macroeconomic effects are transmitted through various channels.

6 The African continent accounts for 93% of cases of malaria and 94% of deaths.
7 According to the World Health Organization's *World Malaria Report 2019*.

Life expectancy as a determinant of growth

The vast majority of theoretical and empirical studies show that improvements in life expectancy have a positive effect on growth. Human capital theory has gradually incorporated individual health as one of its components, since the pioneering work of Becker (1962) who demonstrated that improving nutrition and health systems are ways of investing in human capital. Grossman (1972) developed the first model of demand for health capital, and showed that higher demand for good health increases the number of hours worked as well as hourly productivity. At the macro level, recent panel data studies have used instrumental methods to isolate the causal effect of life expectancy on income growth (Lorentzen et al., 2008; Aghion et al., 2011; Cervellati and Sunde, 2011; Bloom et al., 2014). In a study on OECD advanced economies over the period 1960 to 2000, Aghion et al. (2011) identify productivity gains linked to (i) initial life expectancy, and (ii) its growth. Using cross-country regressions, they show that a reduction in mortality rates in the under-40s leads to increased productivity. In developing countries, the main way to increase life expectancy is by reducing infant mortality; this is associated with an improvement in the physical and nutritional condition of children, which in turn influences their productivity in adulthood.

The macroeconomic impacts are transmitted via various channels

Lower mortality increases savings and capital accumulation

In life-cycle theory, an increase in longevity leads to a rise in the savings rate and an acceleration of capital accumulation (Bloom et al., 2003; Zhang et al., 2003). In an overlapping generations model with life-cycle savings and public education, higher life expectancy has a positive effect on growth in countries where initial life expectancy is low, but weighs on growth in countries where initial life expectancy is already high, as the increase in old-age consumption reduces investment in human capital. The average age at which individuals receive their inheritance tends to increase, while the age of the median voter also rises, leading to a reduction in the tax rate for public education.

Lower mortality and the fertility transition lead to a rise in GDP per capita in developing economies

In developing countries, high adult mortality shortens time horizons for decisions and is associated with increased levels of risky behaviour as well as higher fertility (Lorentzen et al., 2008). Lower rates of mortality and morbidity, combined with access to birth control techniques, in particular for women, help to reduce fertility and improve development (Galor and Weil, 2000; Bloom et al., 2015). Healthier women are also more able to participate in the labour market. Fertility may fall as a result of economic development, as it becomes relatively more costly than education, according to Becker and Lewis's (1973) "quality-quantity" interaction hypothesis. The successful treatment of infectious diseases leads to a decline in fertility, which is linked to higher returns on education (Bleakley and Lange, 2009). Cervellati and Sunde (2011) show that increased longevity has a positive effect on growth in post-transitional countries, but a non-significant effect before the onset of the demographic transition since it increases the size of the population. In developed countries, climate change generates economic costs by lowering the rate of fertility which is already below the replacement rate (Barreca et al., 2018).

Environmental and climate conditions affect labour market participation and labour productivity

Illness directly impacts effective working times in two ways: (i) absenteeism and a reduction in the labour supply (extensive margin); and (ii) presenteeism and a reduction in hourly productivity, for example because of poor concentration due to illness (intensive margin). A number of studies identify a direct link with environmental factors. According to an empirical study by Hanna and Oliva (2015), a 1% rise in the local concentration of sulphur dioxide – one of the main atmospheric pollutants since the start of the Industrial Revolution – reduces the number of hours worked by 0.72%. In OECD countries, air pollution is estimated to have caused 1.2 billion lost working days and 5 billion restricted activity days in 2010 (OECD, 2016), and these numbers are projected to triple by 2060. Even at levels well below US air quality standards, ozone pollution is found to have a significant impact on productivity (Graff Zivin and Nidell, 2012).

Environmental factors also have indirect effects on labour via performance. For example, the exposure of students on exam days to air pollutants that temporarily impair their mental acuity can reduce long-term labour productivity due to a poor assessment of skill levels, which results in inefficient worker allocation across occupations (Lavy et al., 2014).

Persistent effects on human capital

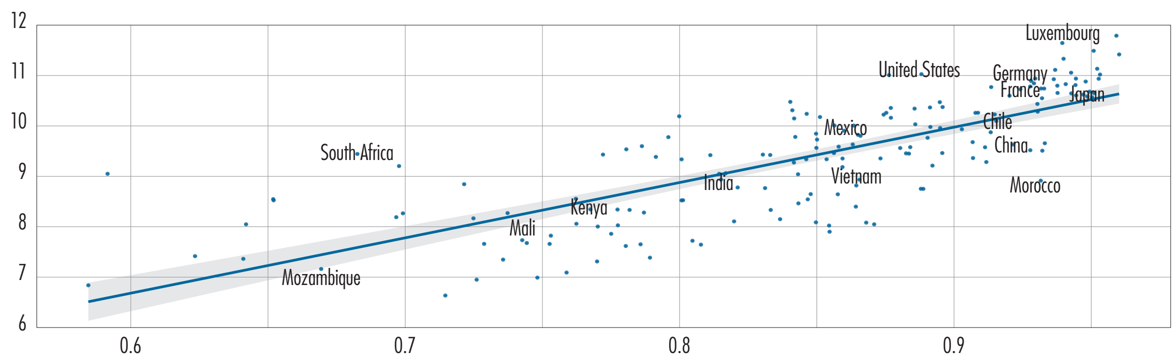
Increased life expectancy encourages investment in human capital (Jayachandran and Lleras-Muney, 2009; Cervellati and Sunde, 2013). In developing countries, poor living conditions or illness in early life have significant lasting effects on human capital formation, productivity and adult well-being. Early-life exposure to diseases such as malaria can have long-run impacts on educational attainment and income in adulthood (Lin and Shih, 2018). The treatment of nutritional deficiencies or diseases such as malaria improves school attendance and results, especially for girls (Miguel and Kremer, 2004; Field et al., 2009). Pollution can be a barrier to knowledge acquisition because it increases absenteeism among students and reduces their ability to concentrate (Lavy et al., 2014). In Indonesia, Maccini and Yang (2009) find that higher early-life rainfall has positive effects on the nutrition and health of women, as households tend to favour boys in the allocation of food resources during periods of drought. This ultimately has an impact on girls' education and economic status in adulthood. As a result of this behavioural bias, girls are therefore more vulnerable to environmental changes. This justifies implementing development policies targeted at vulnerable groups, for whom short-term shocks may have long-term implications.

Adult survival rates can be used to measure the macroeconomic effects of human health on labour productivity

For many diseases, the costs linked to productivity losses are estimated to exceed the medical costs (Loeppke et al., 2009). However, the macroeconomic importance of these effects is still being debated: macroeconomic studies tend to find larger effects than microeconomic studies. The macroeconomic approach consists in estimating an aggregate production function and breaking down the human capital factor into its different components, including health, while the microeconomic approach involves aggregating the estimated effects at the individual level to derive the impact of health on productivity (Weil, 2007). Bloom et al. (2019) use adult survival rates as an instrument for studying the link between human health and productivity (see Chart 4), and show

C4 Correlation between survival rates and productivity (2018)

(x-axis: survival rate for the 15-60 age bracket; y-axis: log GDP per capita)



Sources: World Bank data (World Development Indicators), author's calculations based on Bloom et al. (2019).
Interpretation: Data on GDP per capita displays an exponential trend, which is usual for economic growth. The coefficient for the linear regression of log GDP per capita over the survival rate in percentage points is $\beta = 0.10976$. It is a geometrical average.
A 1 percentage-point rise in the survival rate for the 15-60 age group is associated with an average productivity gain of 11.6% ($\exp(\beta) = 1.116012$). A 2 percentage-point rise in the survival rate is associated with a productivity gain of 24.6% ($\exp(2\beta) = 1.245479$).
Note: A Pearson correlation test shows a strong positive correlation (and not a causal link) between GDP per capita (in logarithm form) and the survival rate for 15-60 year olds (correlation coefficient of 0.77).

that a macroeconomic model produces similar results to the aggregation of microeconomic effects if health spillovers are taken into account. For a given level of education and capital, a rise of 10 percentage points (0.1) in the survival rate of adults aged 15 to 60 is associated with a 9.1% increase in labour productivity.[8] The convergence between the two approaches suggests that public health measures can play an important role in supporting economic growth.

3 The consequences for environmental policies and their assessment

Macroeconomic models could take better account of climate policies in their medium and long-term scenarios. Economic research needs to quantify and integrate the different dimensions of climate change, including its impact on mortality and human capital.

Macroeconomic models need to incorporate climate policies

The empirical literature confirms the importance of incorporating climate policies into the scenarios used to model the macroeconomic impact of climate change. Mitigation measures are those aimed at preventing future climate change by reducing emissions and preserving carbon sinks; they have an indirect impact on health (for example, via quota markets and building renovations). Adaptation measures are those designed to prepare for the effects of climate change (such as dams, flood barriers, seismic protection or insurance systems), to reduce the impact on populations and improve resilience (Ganten et al., 2010).

The impact of hot days on mortality in the United States – mean temperature above 27°C – has declined significantly: the elasticity is now four times lower than in 1960 (Barreca et al., 2016). The fall may be explained by the diffusion of residential air conditioning. This result suggests that the impact of the climate on mortality in developing countries could decline and converge towards that in developed countries as they gain access to the same adaptation technologies.

However, there are still gaps in the literature on the effects of adaptation measures (Deschenes, 2014). Existing studies cover only a small portion of the possible adaptation measures, and there are some methodology issues. For example, several studies focus on measures such as the use of air conditioning (Deschenes and Greenstone, 2011; Barrecal et al., 2016), but calculations of the social value of this technology do not take into account the costs linked to the resulting rise in electricity consumption and greenhouse gas (GHG) emissions.

The empirical literature also suggests that environmental conditions can be considered as factors of production, which could lead to a review of how environmental regulation is modelled (Graff Zivin and Neidell, 2013). While it is frequently represented as a tax in current models, it could be considered an investment in human capital and productivity that fosters growth, with particularly high returns in less developed countries.

Economic research should better quantify and integrate the impact of climate change on mortality and social welfare

There is currently no integrated framework for modelling climate change impacts that takes into account all dimensions of climate change's effects. However, Carleton et al. (2020) propose an empirical estimation of the partial economic costs linked to mortality, and a projection model[9] that incorporates adaptation measures:

- One additional day of hot weather (> 35°C) increases the mortality rate by 4 deaths per million individuals.

- The annual mortality rate linked to climate change is projected to be 85 deaths per 100,000[10] in 2100, compared with 221 without adaptation measures. The hottest and poorest countries will be the worst-affected (160/100,000 in Accra, Ghana). In colder and richer

8 These are just the direct productivity gains, excluding the effects linked to investment in education and other forms of human capital, and those linked to the decline in fertility. The adult survival rate is used as an instrument to measure health, as life expectancy is very sensitive to infant mortality.

9 Empirical estimates of the mortality-temperature relationship are obtained using detailed local daily temperature series spanning several decades, and regional vital statistics in more than 41 countries (55% of the global population). Projections are made for 24,378 regions, based on three population and income scenarios, two emissions trajectories and simulations of 33 climate models, to reduce the uncertainty surrounding the scenarios, and the economic and health data.

10 This corresponds to the current mortality rate for all cardiovascular diseases combined.

countries, the effects will primarily be economic due to the implementation of adaptation measures.

Future research should improve the impact assessment of environmental policies and the quantification of social and abatement costs,[11] to enable a cost-benefit analysis of investments. For example, Sullivan (2016) shows that the research previously underestimated the effects of air pollution because methods for measuring pollution exposure did not take account of wind direction. Using an atmospheric dispersion model, the social value of the reduction in nitrogen oxide in Los Angeles between 1995 and 2005 thanks to the "cap-and-trade"[12] programme is found to be 13 times greater than the abatement costs, whereas analyses based on conventional measures of pollution find no overall social benefit.

Taking account of the impacts of climate change and climate policy on populations is therefore important from a macroeconomic perspective.

11 Costs borne by firms to reduce the pollution or negative externalities that they create (reduction of greenhouse gas (GHG) emissions, cleaning up of contaminated waters): this measures the additional cost of taking climate action relative to inaction, which is calculated as the discounted value of the damage.

12 California's RECLAIM programme, launched in 1994, sets a binding cap on nitrogen oxide (NOx) emissions, and relies on an emissions trading scheme to create a price signal and ensure that the transition is cost-effective. Emission rights can be traded but not carried over from one year to the next, and the emissions cap is lowered each year.

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