

# INNOVATION, GROWTH, AND ENVIRONMENTAL CHALLENGES: SCHUMPETERIAN INSIGHTS INTO CLIMATE CHANGE AND GREEN TECHNOLOGIES

Phillipe Aghion

*Collège de France*

*Institut Européen d'Administration des Affaires  
London School of Economics*

I examine how innovation-driven economic growth can be reconciled with urgent environmental challenges through the lens of Schumpeterian economics. I explore the dynamics of creative destruction—the process by which new firms and technologies relentlessly replace old ones—as the engine of growth and consider its implications for decarbonizing the economy.<sup>1</sup> Turning to climate change, we confront the debate over “degrowth” and argue that halting growth is neither a necessary nor an effective solution to environmental crises. Instead, we advocate directed green innovation—deliberately steering technological change toward low-carbon solutions—as the sustainable path forward. I review evidence of path dependence in technology and show how smart policies can redirect inventive effort. I conclude that achieving the green transition requires multiple policy instruments: pricing carbon to internalize environmental costs and green industrial policies (e.g., R&D subsidies, clean technology support) to overcome innovation market failures.

1. Based on my keynote speech at the Central Bank of Chile’s Annual Conference in 2023.

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## 1. BACKGROUND

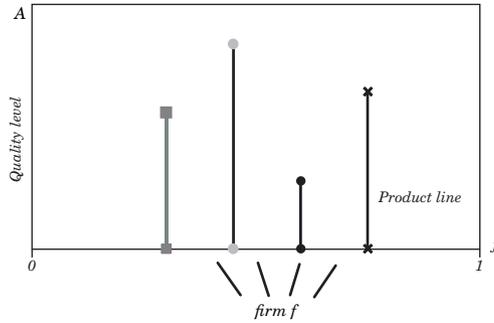
Joseph A. Schumpeter is known for having put forward the notion of creative destruction, i.e., the process where innovations displace old technologies. In his book *Capitalism, Socialism, and Democracy* (1942), he tried to spell out what he meant by creative destruction, but at the time there was no model of Schumpeterian growth. The leading paradigm was the neoclassical model—the Solow model—where growth is primarily driven by capital accumulation, and, under reasonable assumptions of diminishing returns to capital, there can be no long-run growth just by accumulating capital. Solow would point out that technical progress is required to generate long-run growth, but he would not tell you where technical progress comes from.

Peter Howitt and I, in the fall of 1987, noticed this tension and wrote from scratch a model of growth that embodies the notion of Creative Destruction. The model revolves around three main ideas: The first idea is that long-run growth is driven by a cumulative process of innovation where each innovation builds upon previous innovations. The second idea is that innovations result from entrepreneurial activities motivated by the prospect of innovation rents. The third idea is creative destruction: innovations displace old technologies. Innovations make all existing technologies obsolete.

However, the Schumpeterian paradigm reveals a fundamental contradiction. On the one hand, we need monopoly rents to induce innovative activities. On the other hand, yesterday's innovators are tempted to use those rents to prevent subsequent innovation because they do not want themselves to be subject to creative destruction. Thus, regulating capitalism is largely about how to manage this contradictory fact.

This new Schumpeterian paradigm also changed the landscape. First, it gives center stage to cross-firm heterogeneity—between incumbents and entrants, between leaders and followers, between small firms and large firms. In previous growth models, there was no sense of the notion of these kinds of heterogeneities. The model Peter Howitt and I developed was the first framework to capture these dimensions of firm heterogeneity and put them along with firm dynamics as central to the growth process.

**Figure 1. Product-Level Firm Dynamics**



Source: Author's own.

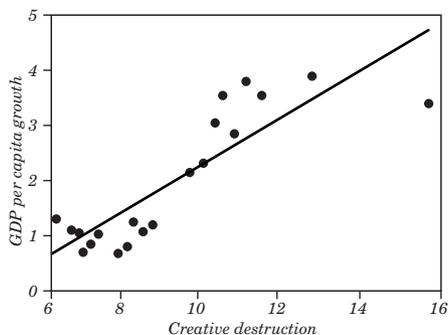
Figure 1 illustrates the firm dynamics in our model, which follows Klette and Kortum (2004), depicting how firms expand or contract based on their success in innovating along different product lines. There is a firm with four lines, each representing a product. The lines are as big as the past innovations that occurred in the product's production process. And, if a firm has that line, it is the only one producing it, with the very best technology to do it. If some firm innovates over the production line of firm  $i$ , and it is successful, then firm  $j$  gets to produce that product, extending one line. The firm  $i$ , on the other hand, loses that product and then loses the line. This model accommodates the expansion and contraction of firms, entry and exit of firms, and emulates the firm size and firm dynamics in a very natural way with the Schumpeterian framework.

### 1.1 Two Distinctive Predictions of the Schumpeterian Framework

Schumpeterian growth theory yields several distinctive empirical predictions, two of which stand out prominently and have been borne out in data. First, higher rates of creative destruction—measured as job or firm turnover—are associated with higher economic growth. Because growth in this framework results from the constant reallocation of resources to innovative firms, one expects to see a positive correlation between measures of firm turnover and aggregate growth. This is indeed what we observe. Figure 2 shows cross-country

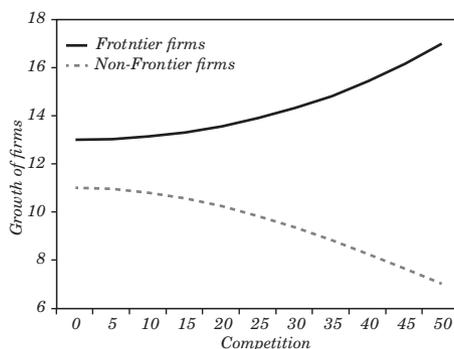
evidence that economies with more vigorous firm entry and exit (or labor reallocation across firms) exhibit higher GDP per capita growth. For example, a country with fluid labor markets and an open environment for startups will likely experience more productivity-enhancing reallocation than one where incumbents are protected, and grow accordingly. Other growth models (e.g., the Solow model or first-generation endogenous growth models without firm heterogeneity) do not generate this prediction.

**Figure 2. Correlation of Growth and Creative Destruction**



Source: Author's calculations.

**Figure 3. Competition, Growth, and Distance to Frontier**



Source: Author's calculations.

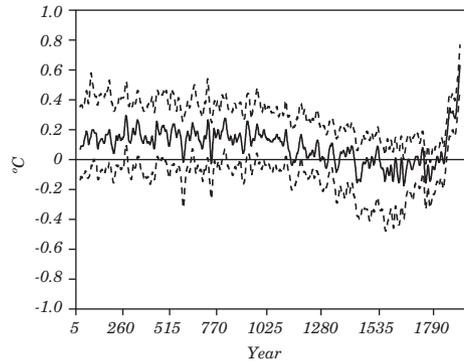
The second prediction from our Schumpeterian model is that more intense competition enhances innovation in frontier firms (leader firms) but discourages it in nonfrontier firms (follower firms). This theoretical prediction arises from two countervailing forces in Schumpeterian models. On one hand, more competition (for example, through lower entry barriers or more rivalrous market conduct) reduces incumbent firms' post-innovation monopoly rents, which could dampen their incentive to invest in R&D—this is sometimes called the “Schumpeterian effect” of competition (Schumpeter himself mused that monopoly profits might nurture innovation). On the other hand, intense competition means a firm cannot take its market position for granted—leading firms under threat will innovate even more aggressively to “escape competition” and widen their technological lead (the “escape-competition effect”), whereas laggard firms might give up because competing head-on with far more advanced rivals yields scant returns. Figure 3 illustrates this prediction. It is produced with UK data, where the solid line shows the frontier firms, the dashed line are the followers, the x-axis is the level of competition (for example, the Lowmarty Index), and the y-axis is the growth of the firms (or it could be the innovation rate of firms). If competition increases in intensity, firms that are already at the frontier are capable of fighting back the competition with more innovation since they are already at the frontier. But for follower firms, the cost of getting to the frontier and starting to innovate increases as it is not that profitable anymore, so they tend to grow more slowly.

## **2. INNOVATION, GROWTH, AND CLIMATE**

In France, we have been arguing with advocates of “degrowth”. According to them, the way to fight climate change is to induce negative growth. But, before getting into the discussion, let me show you some facts that motivate their position.

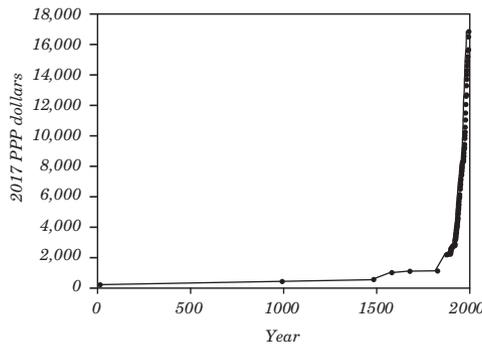
Figure 4 shows that the global temperature remained relatively constant for almost 2000 years, but in the middle of the 19th century, it started to rise sharply at the exact same time as the takeoff of growth, as seen in Figure 5. The similar trajectories in both temperature and product have been understood as evidence that growth led to global warming. Reinforcing this idea, Figure 6 shows that the takeoff of CO<sub>2</sub> emissions of the United States and China occurred precisely at the time when growth took off in both countries.

**Figure 4. Changes in Global Surface Temperature Relative to 1850-1900**



Source: Gillett and others (2021).

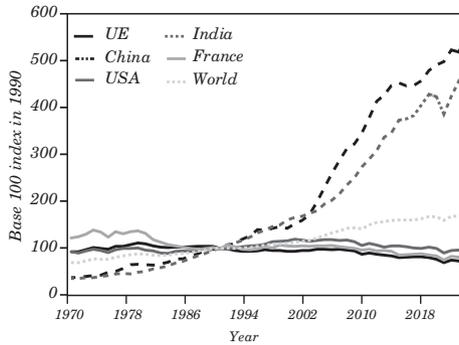
**Figure 5. Global Average GDP per Capita over the Long Run**



Source: Madison Project Database (2025)

But does this mean that we need negative growth to fight climate change? Of course not. Growth has given a lot to humanity. Also, we have already experienced negative growth with the Covid-19 lockdown, and both output and emissions went down, but at a great cost to society.

**Figure 6. Evolution of CO<sub>2</sub> Emissions Worldwide**



Source: Based on IEA-EDGAR CO<sub>2</sub> (2024).

The alternative to negative growth is to have green innovations. The alleged conflict between growth and environmental sustainability is not a fundamental incompatibility, but a challenge of managing a technological transition. Degrowth strategies amount to “fighting climate change with one hand tied behind our back,” foregoing the very tool—innovation and economic dynamism—that can solve the problem. Rather than shrink the pie, we should change the recipe by which the pie is made. As we will discuss, directing innovation towards green technology allows us to both sustain growth and drastically cut emissions. This requires deliberate action because *laissez-faire* market forces left alone may not achieve it in time. But with the right policies and institutions, green innovation can drive a wedge between GDP growth and carbon emissions. The rest of this presentation focuses on how to bring about this directed technological change for the climate.

## 2.1 Directed Green Innovation and Path Dependence

Firms do not spontaneously innovate in green technologies. In Aghion and others (2016), we looked at the automobile industry’s incentives to innovate in green technologies. Using the World Statistics Patent Data at the European Patent Office over the period 1978–2005, we searched for triadic patents, which are patents registered in the European Patent Office, the U.S. Patent Office, and the Japan Patent Office, and can be considered as patents of good quality. From all this data, they classified the patents between “clean” and “dirty”, following

the OECD IPC definition. Something interesting about the database is that you know the history of the patent applicant, meaning that we could track if they patented “green” or “dirty” innovations in the past.

**Table 1. International Patent Classification (IPC)**

<i>Description</i>	<i>IPC code</i>
<b>Clean</b>	
<b>Electric vehicles</b>	
Electric propulsion with power supplied within the vehicle	B60L 11
Electric devices on electrically-propelled vehicles for safety purposes; Monitoring operating variables, e.g. speed, deceleration, power consumption	B60L 3
Methods circuits, or devices for controlling the traction-motor speed of electrically propelled vehicles	B60L 15
Arrangement or mounting of electrical propulsion units	B60K 1
Conjoint control of vehicle sub-units of different type or different functions / including control of electric propulsion units, e.g. motors or generators / including control of energy storage means / for electrical energy, e.g. batteries or capacitors	B60W 10/08,24,26
<b>Hybrid vehicles</b>	
Arrangement or mounting of plural diverse prime-movers for mutual or common propulsion, e.g. hybrid propulsion systems comprising electric motors and internal combustion engines	B60K 6
Control systems specially adapted for hybrid vehicles, i.e. vehicles having two or more prime movers of more than one type, e.g. electrical and internal combustion motors, all used for propulsion of the vehicle	B60W 20
<b>Regenerative braking</b>	
Dynamic electric regenerative braking	B60L 7/1
Braking by supplying regenerated power of the prime mover of vehicles comprising engine-driven generators	B60L 7/20
<b>Fuel cells</b>	
Conjoint control of vehicle sub-units of different type or different function: including control of fuel cells	B60W 10/28
Electric propulsion with power supplied within the vehicle -using power supplied from primary cells, secondary cells, or fuel cells	B60L 11/18
<b>Dirty</b>	
Fuel cells: Manufacture thereof	H01M8
Combustion engines	F02 (excl. C/G/K)

Source: OECD.

Table 1 shows the classification of the patents and their classification between “clean” and “dirty” technologies. Using this data, we performed the following estimation:

$$PAT_{CLEAN,it} = \exp(\beta_{C,P} \ln(FP_{it}) + \beta_{C,1} \ln(SPILL_{C,it}) + \beta_{C,2} \ln(SPILL_{D,it}) + \beta_{C,3} \ln(K_{C,it}) + \beta_{C,4} \ln(K_{D,it}) + \beta_{C,w} w_{it} + \ln(\eta_{C,i}) + T_{C,t}) + u_{C,it}$$

where  $PAT_{CLEAN,it}$  is the number of clean triadic patents by firm  $i$  in time  $t$ ,  $\ln(FP_{it})$  is the fuel price faced by firm  $i$  in time  $t$ ,  $SPILL_{X,it}$  is the spillover for innovation of type  $X$ ,  $K_{X,it}$  is the lagged firm’s innovation stocks,  $w_{it}$  are controls (GDP, GDP/capita, other policies),  $\eta_{C,i}$  is a firm-fixed effect,  $T_{C,t}$  is a time dummy, and  $u_{C,it}$  is a random error. The results are presented in Table 2.

The first result is that, when the fuel price rises, the firm is more likely to innovate clean and less likely to innovate dirty. That is, anything that increases fuel price will tend to redirect innovation from dirty to clean technologies because it becomes less profitable in a market that is shrinking due to the higher fuel price. But the most interesting results come from the stock of clean and dirty patents. Having a higher stock of clean patents increases the propensity to innovate in clean technologies, and having a higher stock of dirty patents increases the propensity to innovate in dirty technologies, thus implying a strong path dependence.

**Table 2. Main Results**

<i>Variable</i>	<i>Clean</i>	<i>Dirty</i>
Fuel price	0.886**	-0.644
$\ln(FP)$	(0.362)	(0.143)
Clean Spillover	0.266**	-0.058
$SPILL_C$	(0.087)	(0.066)
Dirty Spillover	-0.160*	0.114
$SPILL_D$	(0.097)	(0.081)
Own Stock Clean	0.303***	0.016
$K_C$	(0.026)	(0.026)
Own Stock Dirty	0.139***	0.542***
$K_D$	(0.017)	(0.002)
#Observations	68,240	68,240
#Units (firms and individuals)	3,412	3,412

Source: Aghion and others (2016).

Notes: Estimation by Conditional fixed effects (CFX), all regressions include GDP, GDP per capita and time dummies. SE clustered by unit.

This could be bad news: If the economy is operating in *laissez-faire*, the system may get stuck with dirty technologies, on its way to an environmental disaster. The problem is that green innovations do not occur spontaneously. So, there is room for good news: the government can avoid disaster by redirecting innovation towards clean technologies, and early action now can become self-sustaining later due to path dependence.

Now, notice that creative destruction may help in this scenario. Because path dependence is strong, new firms that are entering the market may avoid the problem of transition cost by innovating from the start in clean technologies in a higher proportion than the dirty ones.

Another implication is that we should act now. This is so because, without intervention, innovation is directed towards dirty technologies, thus widening the gap between clean and dirty patent stock. This entails an increase in the cost of intervention that is forcing the firms to move from something they do well (innovating in dirty technologies) towards something they do not have much expertise in (innovating in clean technologies)—in the form of reduced growth as long as clean technologies catch up with dirty technologies.

Table 3 presents the cost of delayed action in terms of consumption estimated by Acemoglu and others (2012) for two scenarios, a ten-year and a twenty-year delay. Measuring the welfare in terms of consumption equivalence, there is a substantial loss from delaying the policies. This is true when we use the discount rate of 1 percent (Stern) and even when we consider a greater discount rate of 1.5 percent (Nordhaus).

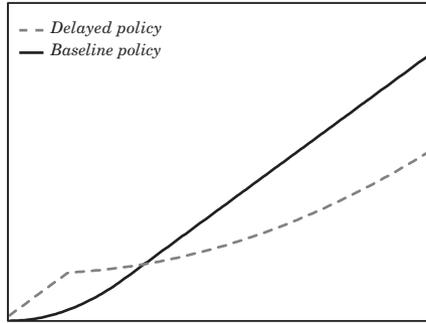
Figure 7 shows the per capita GDP trajectories for these two alternative scenarios. The dashed line corresponds to the delayed policy actions scenarios, while the solid line shows the baseline scenario in which the policy actions are implemented from the beginning. This shows that in the early moments, delaying has a positive impact on GDP because there is no cost of adaptation, but after a few periods, the economy that applied the policies right away surpasses the delayed trajectory.

**Table 3. Main Results**

<i>Discount rate</i>	<i>1%</i>	<i>1.5%</i>
Lost consumption, delay of 10 years	5.99%	2.31%
Lost consumption, delay of 20 years	8.31%	2.36%

Source: Acemoglu and others (2012).

**Figure 7. Per Capita GDP Trajectories**



Source: Author's calculations.

**Table 4. Consumption Loss from Using the Carbon Tax as the Only Instrument to Foster Green Innovations**

<i>Discount rate</i>	<i>Lost consumption</i>
1.0%	1.33%
1.5%	1.55%

Source: Author's calculations.

Another implication of endogenous directed innovation is that we need two instruments because we have two externalities: the environmental one and the knowledge spillovers (path dependence). Thus, another instrument is necessary in addition to the carbon tax to manage the situation. These new instruments are what I call “Green Industrial Policy”.

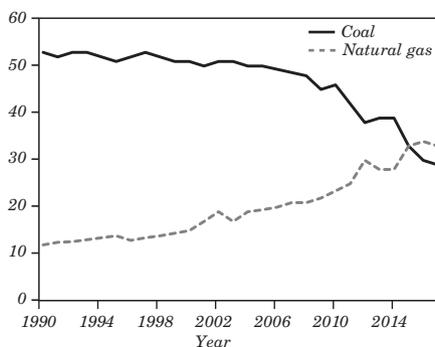
If we only rely on the carbon tax, we will need a higher carbon tax to account for both externalities, which implies a higher loss of welfare. When the discount rate is 1 percent, the consumption loss from using only the carbon tax is about 1.33 percent (as shown in Table 4), with a carbon tax 15 times higher during the first five years and 12 times higher during the following five years.

## **2.2 Reinforcing the Case for Green Innovation Subsidies**

Now, I will introduce an intermediate source of energy (e.g., shale gas). The question that arises naturally in this framework is how

to design the energy transition strategy. The intermediate source is less polluting than coal but more polluting than renewable energy. In Acemoglu and others (2023), we addressed this question using U.S. data.

**Figure 8. Share of Coal and Natural Gas in the U.S. Electricity Generation Sector**



Source: Acemoglu and others (2023).

Figure 8 shows the share of electricity generation for coal in solid line and natural gas in dashed line, from 1990 to 2016. We see that as natural gas becomes increasingly important, coal decreases its share in the same period. Now, as natural gas is an intermediate source of energy, we analyze the short- and long-run effects of an exogenous improvement in the extraction technology of gas (shale gas boom) on aggregate pollution through the lens of a directed technical change model.

In the short run, abstracting from the innovation effect, there are two opposite effects of the shale gas boom: replacing coal by gas (thus reducing the emissions) and the scale effect triggered by the fact that energy costs are cheaper. Notice that the substitution effect will dominate if gas is sufficiently cleaner than coal.

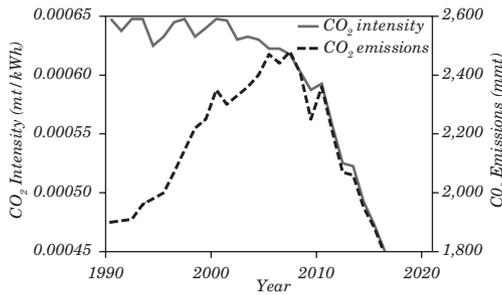
Table 5 shows the results of the calibrated model. Looking at various scenarios of an increase in technology for extracting gas, we can see that there is a fall in  $\text{CO}_2$  emission intensity triggered by the substitution effect (first column), but a rise in the total energy consumed, pulled by the scale effect. Overall, we have that  $\text{CO}_2$  emissions still go down in the short run. This happens because the reduction of intensity is so big that it more than counteracts the scale effect.

**Table 5. Decomposition of Substitution and Scale Effects of the Shale Gas Boom**

<i>Total Effects of Improved Shale Extraction Technology <math>B_{s0}</math></i>			
	<i>%<math>\Delta</math> Emission</i>	<i>%<math>\Delta</math> Energy</i>	<i>%<math>\Delta</math> CO<sub>2</sub></i>
Baseline parameters			
+10% Increase in $B_{s0}$	-16.7%	+5.5%	-12.1%
+50% Increase in $B_{s0}$	-21.0%	+9.6%	-13.4%

Source: Acemoglu and others (2023).

**Figure 9. CO<sub>2</sub> Emissions in the U.S. Electricity Generation Sector**

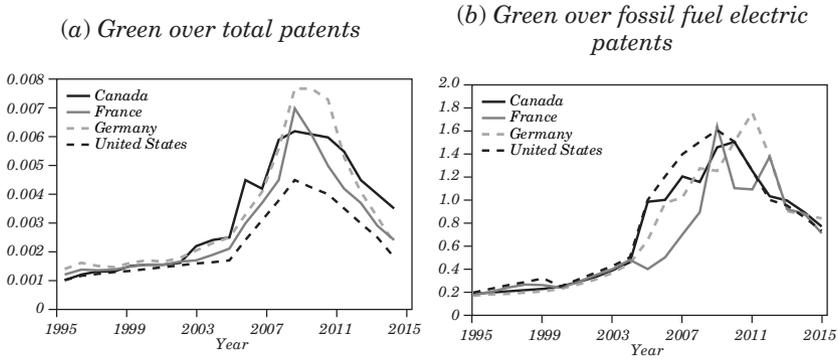


Source: Acemoglu and others (2023).

Figure 9 shows the evolution of CO<sub>2</sub> emissions and intensity in the United States. On the one hand, the intensity was more or less constant until the shale gas revolution and then it fell quickly. On the other hand, the CO<sub>2</sub> emissions were increasing up to the shale gas revolution and then started to decrease. So, at least in the short run, emissions have decreased.

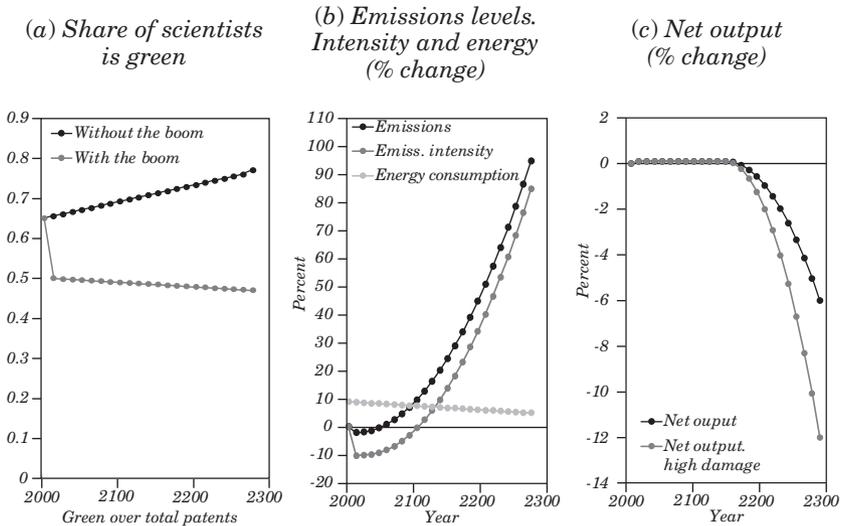
To analyze the long-run effect, we introduce endogenous directed innovation into the model by assuming that power plants can innovate using different sources of energy. Under the lens of the model, the shale gas boom directs innovation away from both coal and clean production technologies, into gas production technologies. This causes a problem in the long run because this process may switch the U.S. economy from a path with declining CO<sub>2</sub> emissions to a path with increasing CO<sub>2</sub> emissions. This could have happened with a fall in clean patents, as shown in Figure 10.

**Figure 10. Clean vs. Dirty Patents in the U.S.**



Source: Acemoglu and others (2023).

**Figure 11. Long Run Consequences of Shale Gas Revolution**



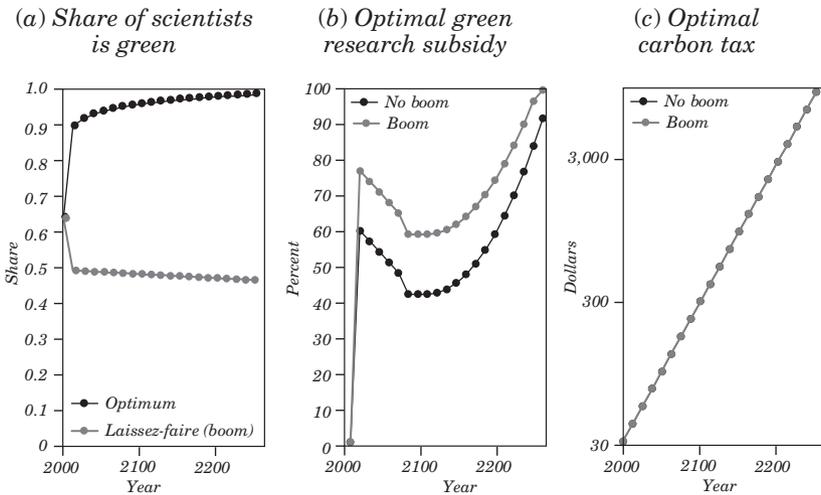
Source: Acemoglu and others (2023).

Or it could also be due to the scale effect, as shown in Figure 11. Panel A shows the path of a scientist working in green technologies with and without the shale boom happening, under the assumption that there is no government intervention. In the scenario where the shale boom occurs, we observe a discrete fall after the boom, followed by a decreasing tendency. The opposite happens in the scenario with

no shale gas boom. Panel B shows the difference in CO<sub>2</sub> emissions between the two scenarios. Initially, in the first 20 years, CO<sub>2</sub> emissions go down because the short-run effects dominate; but then, the emissions will grow at a fast pace, eventually surpassing the emissions in an economy without the boom because the long-run effects dominate. And because emissions will rise, panel C shows a sharp fall in the net output due to greater damages arising from global warming.

So, this long-run effect plays a very important role. In essence, the short-term gains were offset by long-term losses due to diverted innovation, causing the economy to move from a good trajectory towards a bad one. But if the government has the ability to act, then it raises the question of what the optimal policy could be, as there are gains from the boom in the short run. Figure 12 shows the optimal trajectory of the policies. Panel A shows that, to achieve the optimal trajectory, there is a need to compensate for the effects of the boom by adding more scientists researching green innovations as compared to the *laissez-faire* situation. Panel B shows that the subsidy of green research needed to achieve the optimal number of scientists doing green research is greater when the boom happens because we need to counteract the incentive of researchers to divert their efforts towards the shale gas technology. Regarding the optimal carbon tax, it does not change much between the two scenarios.

**Figure 12. Policies' Optimal Trajectory**



Source: Acemoglu and others (2023).

The main idea is that an intermediate energy source boom can be dangerous because it can redirect the innovations towards nonclean once, but it also can open an opportunity to have gains in the short run without losing the path of cleaner technologies if the right policies are applied.

## 2.3 The Role of Civil Society

So far, we have only discussed a role for the state. We argued a role for the state in directing firms' production and innovation. But what about civil society? Can the consumers help in any way? Aghion and others (2023) address this question. We first check if the consumers' valuation of the environment can shift the innovations of the firms towards clean technology.

**Table 6. Regression Results**

	(1)	(2)	(3)	(4)
<i>Variables</i>	<i>Log(1+#clean)-Log(1+#dirty)</i>			
Values	0.170*** (0.0397)	0.229*** (0.0500)	0.233*** (0.0524)	0.594*** (0.144)
Competition	0.189*** (0.0614)	0.161*** (0.0605)	0.325** (0.139)	-0.0223 (0.0305)
Values x Competition	0.109*** (0.0370)	0.0703*** (0.0234)	0.0875*** (0.0231)	0.0620** (0.0243)
Log fuel price	0.766*** (0.235)	0.601** (0.244)	0.151 (0.236)	0.856 (0.663)
Competition measure	OECD	OECD	World Bank	Lerner
Values measure	Higher tax	Index	Higher tax	Higher tax
Observations	17,124	17,124	17,124	2,706
R-squared	0.121	0.122	0.121	0.199
Number of x bvdid	8,562	8,562	8,562	1,854

Source: Aghion and others (2023).

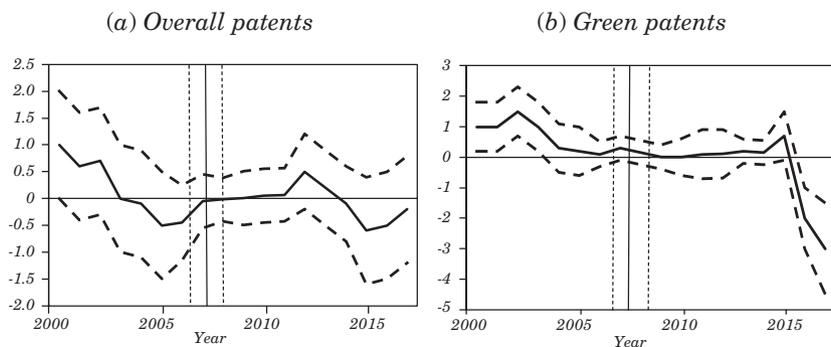
Going back to the automotive industry, looking at the propensity to innovate in green technologies, Table 6 shows the results of a similar regression but considering the countries where consumers value the environment. The variable value is constructed at the firm level as a weighted average of the valuation of each country where it has a presence and using the exposure of the firm to those countries as weights. All the specifications show that the consumers' valuation of the environment shape the firms' decisions on innovation.

Now, let's talk about competition. Increasing competition could have two effects. The first one is a scale effect. The competition can reduce prices, thereby incentivizing consumption and boosting output, which ultimately increases emissions. But on the other hand, if consumers value the environment, more competition induces more green innovation, thereby reducing emissions. This happens because innovation is a tool used by firms to escape competition. Going back to Table 6, the third row captures this effect of the interaction of competition and value. Notice that the relation is positive in all specifications. This means that educating consumers and inducing more competition can have effects as important as a carbon tax.

### 3. CONCLUSION

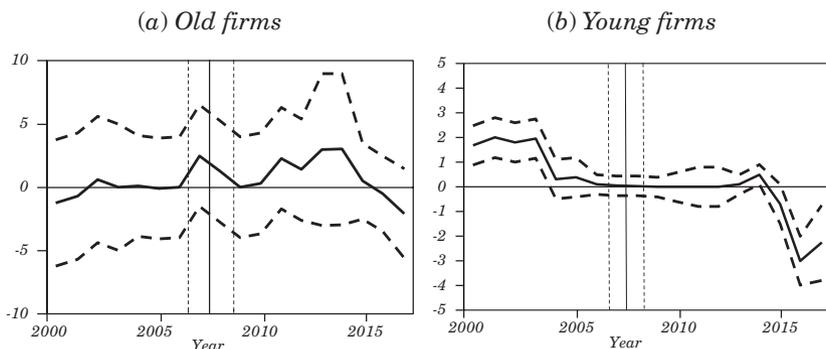
There are three big conclusions for this paper. First, innovation-based climate-change models suggest that *laissez-faire* leads to disaster due to path dependence in the direction of innovation. Second, one must act now, and multiple instruments must be used, not just the carbon tax. Third, there is a direct link between firms, the state, and the civil society. Firms innovate, so they are necessary. But they do not spontaneously innovate in green technologies, so we need the state to redirect the innovation towards green technologies by imposing a carbon tax, green industrial policy, etcetera. Civil society also has a role to play. Consumers (and not only they but also the media and other forms of communication) can discipline firms.

Digging into Green Industrial Policy, in Aghion and others (2024a), we consider the green energy transition along the value chain in the presence of Pigovian taxation. Complementarities across sectors can lead to multiple equilibria either where clean technologies are adopted along the value chain or where they are not adopted. This speaks to the role of industrial policy to coordinate the clean transition because with a Pigovian tax alone to remove multiplicity, one would need too large a tax.

**Figure 13. Evolution of Patents**

Source: Aghion and others (2024a).

Notes: The figure plots the effects of exposure to Commerzbank on patenting in the year on the horizontal axis. Estimates from PPML. Confidence bounds are at 95% level using firm-clustered standard errors.

**Figure 14. Evolution of Firms**

Source: Aghion and others (2024a).

Notes: The figure plots the effects of exposure to Commerzbank on patenting in the year on the horizontal axis. Estimates from PPML. Confidence bounds are at 95% level using firm-clustered standard errors.

Also, there is a role of finance. Finance is particularly helpful in understanding the financing of new firms. As we saw, endogenous directed innovation favors new firms because they do not have the burden of path dependence. That is, anything that will ease the entry of new firms could help with the process of green innovation, and the same is true when entry becomes costly. In Aghion and others (2024b), we look at the effect of exposure to German banking crises on green innovation. There is a fraction of firms that have links with Commerzbank. During the crisis, Commerzbank had to cut lending

after losses in its international trading portfolio. Figure 13 presents the results of a difference-in-difference approach.

For “overall patents”, there is no difference in being a bank that suffered the crisis, but for “green patents”, there is a slope. Figure 14 shows the patents by young and old firms. For old firms, the patents remained stable, unlike the new firms, which dropped. And we know that the new firms are the ones that do not have the path dependence cost, so they innovate more in green technologies.

Thus, the problem is that when we have a credit crunch, the firms that are harmed the most are the new ones, that is, the ones that are more prone to do green technology innovation. This stands out because it has implications for macro policy. From a monetary point of view, raising interest rates too much will slow down the transition to a low-carbon economy because it will make it difficult to finance small and new firms. From a budgetary standpoint, the management of public debt is relevant. Cutting subsidies for green technologies may save money, but this will imply that firms will continue to innovate in a dirty way because of path dependence, and it will be much more costly to make the transition later. So, in a sense, we will be leaving future generations with a huge environmental debt. Therefore, it is necessary to arbitrate between these two debts.

As a final point, it is important to recognize that there are different types of innovation. First, there is mitigation innovation, which aims to reduce the rise in temperature (such as the discovery of new energy sources). Next, we have adaptation innovation, like air conditioning, which helps us adapt to global warming. Finally, there are innovations focused on cooling, which seek to lower global temperatures. The question is—can we master this technology to achieve cooling? These types of innovations can be categorized into two broad categories. “Plan A” innovations, which aim to mitigate the effects of environmental degradation, and “Plan B” innovations, which are designed to help us survive in a warmer world. Some argue that focusing on Plan B innovations could undermine Plan A efforts. However, I disagree, because countries will not adopt Plan A or Plan B innovations simultaneously. Therefore, to effectively address the unique needs of each country, it is crucial to have all available tools at their disposal.

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