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Economic freedom and the greenhouse gas Kuznets curve

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ABSTRACT

If and how economic freedom is associated with environmental damage remains an open question. In this paper, I therefore combine data on greenhouse gas emissions and GDP per capita with the Economic Freedom of the World indices to test if economic freedom affects emissions. I do so in the context of estimating a standard Environmental Kuznets Curve in which economic freedom can both reduce overall levels as well as shift the shape of the curve. The results suggest that economic freedom reduces greenhouse gas emissions but also shifts the top point of the Kuznets Curve to the left.

1. Introduction

One of the most important and politically controversial questions today is whether economic growth and environmental sustainability are inescapably in conflict with each other, or if further growth and productivity improvements are necessary to solve global environmental problems. While many economists remain optimistic with respect to the ability of market economies to deal with climate change and environmental problems, many others including leading members of the United Nations' IPCC panel and the Swedish activist Greta Thunberg passionately argue against free markets and in favour of draconic political measures restricting economic and individual freedom.

Politics aside, it remains an open question if societies characterised by economic freedom are associated with more environmental damage. On one hand, more government control and regulation could in principle force firms and individuals to reduce pollution, environmental damage and greenhouse gas emissions. On the other hand, more economic freedom is likely to enable innovation and incentivise the adoption of green technological development. Whether free markets create environmental damage or enable societies to find and implement solutions to such problems is an empirical question.

In this paper, I therefore combine data on growth in CO_2 and other greenhouse gas emissions and GDP per capita with the Fraser Institute's Economic Freedom of the World indices in order to test if economic freedom affects emissions. I do so by estimating a standard Environmental Kuznets Curve (EKC) in which economic freedom can both affect overall *levels* as well as shift the *shape* of the curve. The EKC describes how the size and scope of environmental problems change during the course of economic development (Dasgupta et al., 2002).

The main innovation in this paper therefore is that the empirical framework not only yields estimates of pure level effects of economic freedom (cf., Lundström and Carlsson, 2003; Adesina and Mwamba, 2019), but also allows me to assess the degree to which the quality and timing of environmental transitions depend on economic freedom. The available data from 155 countries observed in

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five-year periods between 1975 and 2015 indicate that economic freedom not only reduces overall CO_2 emissions but also shifts the top point of the EKC to the left. As such, the evidence suggests that the transition to lower emissions technology appears at an earlier stage in economically freer societies.

The rest of the paper is structured as follows. Section 2 outlines the theoretical considerations in favour of and against intervention and state control. Section 3 describes the data and the empirical strategy used in Section 4. Section 5 discusses the results and concludes.

2. Theoretical considerations and previous literature

Considering the theoretical association between the degree of government intervention and control and emissions of greenhouse gases – and thus between economic freedom and emission dynamics – the related literature offers conflicting mechanisms and concepts of government. In the following, I outline the most important *dynamic* theoretical arguments for and against government intervention and control. Particularly, I distinguish between static arguments that deal with the best allocation of given resources and use of known technology and dynamic arguments resting on the speed with which an economy changes its use of resources and develops or adapts new and previously unknown or unused technology.

2.1. Arguments in favour of state control: neoclassical economics

Some of the arguments in favour of state control and intervention rest on the neoclassical argument popularised by public economics that most pollution problems are essentially problems of negative externalities (Barr, 2012). This may be a particular problem in democracies, as indicated by Hailemariam et al. (2020) who outline a "marginal propensity to emit approach", which implies that the greater the income grows, the more carbon emissions occur. The problems of environmental externalities have been known since Pigou's (1932) seminal work, where he argued that an unregulated market would produce emissions above a social optimum. However, the argument is not only about the static properties of a free market economy, but also about its dynamic development. A modern version of Pigou's argument that the private costs of emissions are lower than the true social costs implies that private firms in a market economy have sub-optimal incentives to invest in low-emissions technology because they do not bear the full costs of their emissions. Similarly, Stern (2008) argues that regulation can speed up innovative activity by allowing firms to exploit economies of scale and providing regulatory certainty to the relevant industries. As such, negative externalities may hold back innovative investments needed to reduce CO_2 emissions and other types of pollution.

A similar externality argument is often made for innovative investments and investments in research and development in general. First, when firms cannot prevent others from appropriating their technology and innovation, the profit motive behind investing in such technology and the supernormal profits necessary to recoup the often highly risky investments disappear. These problems may require government action such as general support for basic research, research subsidies and tax exemptions for certain types of investments, as well as the allocation of patent rights (Griliche, 1986; Jones and Williams, 1998; Stern, 2008). Second, non-innovative firms may also lack the absorptive capacity to implement new technology as emphasised in the literature on foreign direct investments (cf., Borensztein et al., 1998). Given such problems, a case can be made for government-mandated and possibly also government-funded education and vocational training to overcome the problem, if it is endemic to most firms.

Third, as emphasised by Munger (2008), private firms as well as individual voters may lack information on the extent of the problems as well as possible solutions and new technology. Specialised knowledge may require particular expertise that many firms do not have, and information on new technology and knowledge may be proprietary. Both problems will lead to reduced adoption of clean technology while a lack of information among voters and consumers may both affect their political behaviour and the extent to which they reward firms or products that are perceived to be less resource-intensive or produced in a 'cleaner' way.[1] Government-provided information campaigns and information banks may be necessary to overcome these types of problems.

Finally, credit constraints can prevent firms from undertaking potentially profitable, but risky investments. Large-scale innovative activity as well as wholesale implementation of clean technology constitute large bulk investments, which may be beyond the scope of many firms due to either credit constraints that may make it impossible for firms to finance the investments or owing to high transition costs. This may require government coordination of an entire industry, government-run or government-mandated national development banks that provide loans to innovative activities and, in the present case, to investments in the development and implementation of clean/green technology, or public regulation and subsidisation of financial institutions in order to provide sufficient loans. Firms may also be helped by the adoption of green public procurement rules that help create larger markets for low-emissions technology.

2.2. Arguments in favour of state control: heterodox and Marxist economics

However, a number of scientists and political commentators maintain that arguments from standard neoclassical economics and public economics are far from sufficient to characterise the entire problem. Their additional arguments and theorising are sometimes

[1] However, a further problem is when there is disagreement about facts. A pertinent example occurred in the spring of 2019 when a study from the prestigious CESIfo Institute in Munich found that the life-cycle carbon footprint of a popular electric car can exceed that of a similar-sized Mercedes Benz diesel car (Buchal et al., 2019: The study was attacked by the German car industry as well as interests within the renewable energy sector (*die Forschungsgesellschaft für Energiewirtschaft* and *Agora Energiewende*) and fiercely debated in the German media.

characterised as 'heterodox economics' although the arguments range from variations on standard welfare economics to full-blown Marxist analysis.

A common feature of these arguments is that they all rest on claims that there are fundamental problems with a free market economy that prevent any market-conform policies from being effective. A common claim underlying many such arguments is that a capitalist economy is inherently characterised by short time horizons/high discount rates in economic decision-making and thus also short effective time horizons in investment behaviour. The short time horizons create problems equivalent to externalities when future costs are heavily discounted.[2]

A first theoretical argument for problems with inherently short time horizons – what Schulman (2019, 12) calls "the very externalities capitalism has itself generated" – comes from Marxist theory. While, as Stigler (1950) explains, modern price theory emerging from the simultaneous work of Jevons, Menger and Walras rests on the foundation that prices are reflections of subjective preferences revealed in market interactions, Marxist theorists continue to reject subjective theories of value. They instead follow either Marx's labour theory of value or other versions of cost theories of value, which allows them to argue that prices revealed by a free market economy are fundamentally inefficient and ought to be replaced by what is termed 'socialist reproduction prices'.

As Laibman (2013, 504) argues, "Socialist reproduction prices result from calculation of direct plus indirect resource use by enterprises, and also embody the long-time horizons necessary if the society is to address looming ecological constraints and requirements of sustainability." The insistence on applying the type of cost theory of value, as exemplified by Laibman, also logically implies that capitalist economies will suffer from substantial coordination problems when economic coordination rests on capitalist market prices (cf., Hayek, 1945). Modern Marxists thus argue that capitalist economies not only are ecologically unsound, but also fundamentally unproductive.[3]

However, another non-Marxist argument also holds that a free market economy entails time discount rates that are substantially higher than socially optimal. This is the approach taken by the much-discussed *Stern Review* – a report on climate change and climate policy commissioned by the British government – which applies ethical considerations in favour of a much lower discount rate than what follows from most standard economic studies (Stern, 2007a). Stern (2007b, 8) argues that any application of standard estimates of individuals' discount rates "involves discrimination between individuals by date of birth," and claims that ethical considerations of intergenerational neutrality logically require the use of a discount rate close to zero. Stern thus arrives at similar policy implications as Marxist thinkers, although from a very different theoretical starting point.[4] In both cases, the implication is that the intervention and control by both national governments and institutions of global governance are necessary, as free market economies in their view are unable to deal with environmental problems in general and cross-border externalities in particular.

Finally, an alternative and quite different argument derives from the politically influential work by Mazzucato (2013). Contrary to standard approaches to supporting basic research (Griliches, 1986; Jones and Williams, 1998), Mazzucato argues in favour of direct government control of the allocation of entrepreneurial resources and activity. Her argument rests on two main claims: 1) that a free market economy rewards so-called "value extractors" more highly than value creators; and 2) that firms such as large financial corporations, high-tech corporations and the pharmaceutical industry are value extractors that capitalise on the innovation created by state research agencies and public universities – the value creators. Combining these assertions, she claims that most successful technical innovations the last 60 years have been the results of government-run research, and not any form of private or market-driven activities.

Mazzucato's main argument rests on the assertion that when value is conceptualised as the price a good, service or innovation can fetch in a free market, capitalists can enrich themselves by manipulating prices and thereby become rich without contributing actual 'value' to society. She views this type of behaviour as a market failure to be alleviated by government such that the entrepreneurial talent currently flowing into value extraction is redirected to innovation and contributions to sustainable growth. While her argument thus is laid out as a market failure problem, it rests on a non-subjective theory of value, and thus a similar concept of value and prices as used in Marxist theory. It follows that the price of and value to society of innovative activities, as well as the pricing of pollution and CO_2 emissions cannot be gauged from market activity, but must be assessed differently by government.

Mazzucato (2013) is hence one of several academics to propose the creation of a government-owned National Investment Bank to

[2] A somewhat peculiar problem is that if economic actors *in general* suffer from short time horizons, then they will apply the same preferences when acting as voters. Unless one makes asymmetrical behavioural assumptions, voters will thus have short time horizons that they force upon political decision-making, which implies that one cannot leave the question of how to deal with environmental problems to democratic decisions.

[3] It should be noted that although many modern Marxist economists continue to rely on cost theories of value, Oscar Lange's response to the Austrian challenge to socialist thinking was more advanced. Lange (1937, 125) invoked Pigou's then new theory of externalities by arguing that in a capitalist economy, "Most important alternatives, like life, security, and health of the workers, are sacrificed without being accounted for as a cost of production. A socialist economy would be able to put all the altematives into its economic accounting." He thus combined the use of subjectivist value theory with arguments for substantial and endemic externalities to argue for the superiority of organising the economy along socialist lines. In an appendix about the allocation of resources to his two-part article on the viability of a socialist economy, Lange (1937) laid out the case while chastising fellow socialists for sticking to Marx's labour theory of value. In the same line of work, Lange maintained his insistence on citizens' full freedom of consumption, which he tried to make compatible with the top-down organisation of a socialist economy.

[4] Many economists, vividly represented by the later Nobel Prize recipient William Nordhaus, have been highly critical of the *Stern Review*'s near-zero discount rate. Nordhaus (2007, 688) is particularly scathing, calling the review a "thicket of vaguely connected analyses and reports on the many facets of the economics and science of global warming" and criticising Stern's radical policy proposals.

fund innovative activity and a transition to a sustainable low-carbon society.[5] The implications of her theoretical considerations and examples is that private firms are rarely innovative and resources should flow to government-run or government-mandated research and development activities. In order to further innovative activity, Mazzucato requests a substantial expansion of government spending and government control of large parts of the economy. Such implications are echoed by many other academics who share her theoretical starting point and her conceptualisation of value to society. Blakeley (2019), a Marxist economist, exemplifies this view of optimal policy by describing what is needed as "democratic public ownership over most of the economy, dramatic increases in state spending, and the controls on capital mobility required to achieve this." Interestingly, she as well as many other economists within this tradition thus seems to recognise that most private firms would move their activities out of a country that implemented her policies without also implementing strict capital controls practically equivalent to expropriation. All of these arguments can be subsumed as calls for very substantial reductions in economic freedom as a way – and arguably the only way – to further a transition towards lower greenhouse gas emissions and less pollution.

Overall, a variety of arguments exist from market conform regulations and supplementary government funding for basic research to calls for an autocratic Marxist economy. However, a correspondingly large number of arguments exist in favour of the effectiveness of a free market economy to which I now turn.

2.3. *Arguments against state control: knowledge in the Austrian tradition*

In order to outline the arguments in favour of a market economy characterised by substantial economic freedom contrary to extensive government intervention, a natural starting point is what is known as the socialist calculation debate of the 1930s. I will subsequently turn to the related incentive problem as laid out by the public choice school of thought.

The knowledge problem in political decision-making and bureaucratic processes was first described by von Mises (1920, 1944) and Hayek, (1937). In insights originally developed by von Mises (1920) in the wake of the Russian Revolution, the emerging Austrian school of economics first came to emphasise what is known as the 'local knowledge problem'.[6] While proponents of interventionist approaches implicitly assumed (and continue to assume) that all relevant knowledge is already known or knowable and available to planners, a large share of the data required for rational economic planning is distributed among individual actors and thus unavoidably exists outside the knowledge of a central authority. While Lange (1936, 55) had argued that "The administrators of a socialist economy will have exactly the same knowledge, or lack of knowledge, of the production functions as the capitalist entrepreneurs have", Hayek (1945, 519) later noted in his seminal work on the use of knowledge in society that:

> If we possess all the relevant information, if we can start out from a given system of preferences, and if we command complete knowledge of available means, the problem which remains is purely one of logic. That is, the answer to the question of what is the best use of our available means is implicit in our assumptions. This, however, is emphatically not the economic problem which society faces. And the economic calculus which we have developed to solve this logical problem, though an important step toward the solution of the economic problem of society, does not yet provide an answer to it. The reason for this is that the "data" from which the economic calculus starts are never for the whole society "given" to a single mind which could work out the implications and can never be so given.

In the context of government regulation, no bureaucrat can therefore ever know all the relevant particulars necessary to effectively devise, implement and enforce regulations or direct government control of parts of the economy. While some information about the technology and production processes applied in private firms may be available, although at a considerable cost, these characteristics are likely to change over time. In other words, bureaucrats must dynamically adjust regulatory policies, as they are aiming for a moving target. Yet, much knowledge at the firm level – including knowledge related to innovation activity and entrepreneurial tasks – is also likely to be tacit and thus not codifiable and may even be computationally intractable at the firm level (Decanio, 1999). These problems create the situation known as 'Hayek's Institutional Design Problem' in which the bureaucracy and political decision-makers do not only lack sufficient unbiased information with which to design regulatory policy, but where firm behaviour is affected by the regulatory framework (Munger, 2008). As regulation changes firm behaviour, information about firm behaviour in the absence of regulation and thus information about the very market failure or other problems that regulatory policy is supposed to solve is destroyed by the regulatory policy itself.

In addition, the process of bureaucracy does not allow for the type of learning through empirical trial and error that is necessary to *reveal* what works and what does not (Stigler, 1971). The knowledge problem also represents a significant problem for any attempt at substantial policy coordination and not just the implementation of single interventions (Greenwood, 2015). In a dynamic context, these problems are specifically challenging, as one cannot predict *ex ante* which new technologies, innovations and changes to production processes work better or lead to cleaner outcomes and lower emissions. As Hodgson (1999) emphasises, the type of trial and error learning that is inherent in any form of research and development requires structural 'impurities' in the economy in the form of

[5] Mazzucato's ideas have been so influential that the European Union's Horizon Europe program, a 100 billion euro research and innovation program, includes several of her policy ideas.

[6] Much of the thinking in welfare economics and most particularly in heterodox and Marxist theories are associated with a French positivist tradition in which it is possible to provide a sufficient solution to any problem trough a theoretical analysis (Hazareesingh, 2015). These contributions thus mostly rest on purely deductive reasoning that is often anti-empirical. It is thus ironic that some modern strands of Austrian economics are equally critical of virtually all empirical work.

multiple types of production and organisation, and a dynamic market economy to reveal which new forms may be superior to other forms.

Some of these structural impurities are created by entrepreneurial activity when entrepreneurs particularly alert to yet undiscovered opportunities experiment with changes to products, production processes, management procedures and other innovative behaviour (Kirzner, 1973). More pertinently to the present discussion, in Schumpeter's (1943, 132) conception of entrepreneurs, their role in the economy is "to reform or revolutionise the pattern of production by exploiting an invention or, more generally, an untried technological possibility …" As Ricketts (1992) emphasises, this is a much more encompassing and demanding role than mere alertness, but also one that is central to the dynamic development of society as entrepreneurs alleviate the particular problem of Knightian uncertainty – of the nature of future technology and innovation as an unknown unknown (Knight, 1921).

In many instances, Kirznerian and Schumpeterian entrepreneurs thus *react* to market failures as such failures represent profit opportunities not yet exploited by other actors. Similarly, entrepreneurs will react to increasing prices of specific resources by investing in resource-saving technology and in developing substitutes to the scarce resource (Simon, 1981). Entrepreneurs thereby do not simply react to mispricing of environmental value or externalities, but in this perspective actively react to solve such problems. Not least in the dynamic context of resource-saving and low-emissions innovation, such entrepreneurial activity is an important private mechanism with which societies become more productive and less dependent on specific resources. Yet, as a growing literature has documented in recent years, it is in general economically free countries that generate more entrepreneurial activity and thereby become more productive (e.g., Bjørnskov and Foss, 2016). In other words, empirical evidence suggests that more government control, more government production and regulatory intervention is associated with substantially *slower* dynamic development of the kind necessary to reduce pollution and the emission of CO_2 and other greenhouse gases.

As originally conceived by von Mises (1920) and Hayek (1937), the lack of knowledge – through the inability of bureaucracies to access the dispersed knowledge of millions of private firms and decision-makers as well as the impossibility of accessing knowledge about future technology and opportunities and thus of any knowledge about dynamic opportunities – implies that government interventions, regulation and control are not likely to be viable long-run solutions to environmental problems. However, even if such problems could be solved, as claimed in sections 2.1 and 2.2, the incentive structures of political and bureaucratic decision-making may prevent such solutions from being viable. This is the last theoretical problem, which I now turn to.

2.4. Arguments against state control: incentives and problems of public choice

A final line of arguments comes from public choice and focuses on incentive problems in politics and the bureaucracy. A long line of research since Buchanan and Tullock's (1962) seminal work has documented that while there are market failures, there are also frequent and entirely predictable government failures that must be taken into account.

First, the public choice approach questions whether all problems of adverse firm behaviour are due to market failures. Reflecting the main question in this line of research, Keech and Munger (2015) argue that many situations that are regularly diagnosed as market failures are in reality government failures because governments shape formal institutions, which define the incentive structure of private firms and citizens. A standard neoclassical prescription is, as emphasised above, to allocate and enforce patent rights, thereby giving private firms the economic incentives to invest in risky innovate activities and plan on a long-time horizon. Yet, if the political incentives of government are inconsistent with the existence of an effective and politically independent judiciary that can enforce such rights, *de jure* patent rights and more general protection of private property rights are unlikely to yield private incentives to invest (cf., Aidt et al., 2018). This is often claimed to be the situation in China, but Latin American history also includes several examples of industrial special interests with close connections to political parties. In all situations, the executive has a strong incentive to override or control the judiciary in order to make sure that it takes decisions favourable to the special interests.

Second, a similar problem can be created when governments' electoral support either changes or implies a premium on visible political activism. The institutional and regulatory uncertainty created by frequent policy changes, many of which are difficult to forecast, implies that private firms come to operate with effectively short time horizons. As documented by Baker et al. (2016), substantial policy uncertainty leads many private firms to either postpone or entirely cancel many investments and may lead them to plan on a shorter time horizon. The short time horizons and heavy discounting of the future that Marxist and heterodox approaches attribute to market failures or inherent features of a free market economy may therefore be the results of government failures, and thus a reflection of the diametrically opposite institutional situation.

As such, research within the public choice tradition emphasises that the private incentives of politicians and bureaucrats are at least as problematic as the private incentives of firm owners and are in many cases the origin of negative externalities. Some of these incentives derive from the desire to be re-elected or stay in power through other means and thus from what Keech and Munger (2015) categorise as "procedural failures" that can cause collective decisions to be unpredictable, arbitrary and occasionally manipulated. Another type of political incentive with similar problems derives from corruption, lobbying and other types of rent seeking, which Keech and Munger term "substantive failures."

The latter type of public choice problems has the potential of undermining the effectiveness of government action, even if one ignores the Austrian emphasis on knowledge problems. As noted by Olson (1965), organised special interests can often exert substantial influence over policies and institutional choices by providing campaign funding and other political support in return of policy

in favour of the interests. These interests may be private firms and non-government organisations as well as labour unions trying to protect jobs for union members.[7] Moreover, Hillman (1982) shows that firms in declining industries have stronger incentives to rent-seek than firms in more profitable sectors. Less productive, resource-intensive and older firms are thus both more interested and often better positioned to seek rents while younger, more productive and resource-efficient firms are likely to be less interested and not sufficiently connected to do so. As such, special interest politics will most often favour industry incumbents and less productive sectors, and thus most likely also firms competing with modern, low-pollution and low-emissions industry (cf., Grossman and Helpman, 2001). These firms typically use political influence to gain protection from international trade and foreign direct investments that often bring new and more environmentally friendly technology (Demena and Afesorgbor, 2020). While the type of industrial policy advocated by both some neoclassical economists as well as political advisors such as Mariana Mazzucato may in principle be well intended, it is almost always *de facto* problematic and counter-innovative.

A related problem is that Hayek's institutional design problem is not only created by government, such that the very act of attempting to regulate private behaviour implies that government loses the ability to effectively alleviate environmental problems, even if all relevant political actors are benevolent (Munger, 2008). Laffont and Tirole (1991) use monopoly regulation as an example with which to show how informational asymmetries not only prevent government from regulating firms efficiently but can incentivise regulatory capture. The information, which bureaucratic regulators need to implement and enforce regulation, must under many circumstances come from regulated industries themselves. This implies, as Stigler (1971) originally noticed, that established firms and industries that are supposed to be regulated can affect the regulations through the information they supply, as well as through more regular and potentially corrupt rent-seeking associations with the bureaucracy (Treisman, 2000; Kingston, 2007).

In addition, although it is usually assumed that the influence runs from firms to politicians, McChesney (1987) argues that policy-makers may actively create rents, for example in the form of particular political privileges, in order to extract funding and privileges from industry. This complex of problems of political rent-seeking and regulatory capture often benefits incumbents and keep new and potentially innovative firms out of the market (Bradley and Klein, 2016; Tollison, 2012). Many studies thus find that the regulatory burden on regular firms is most likely above the optimum and regulation in the long run exerts sclerotic effects on investments (Coates et al., 2010; Heckelman and Wilson, 2019). Such problems multiply in case government takes over industry itself in the form of either direct nationalisation or through extensive political regulation, as attempts to avoid rent seeking through such means risk creating government monopolies with no incentives to economise on resources – a situation that was painfully obvious in communist countries (Bjørnskov, 2018).

Overall, claims of a 'climate crisis' and similar arguments may thus be convenient justifications of substantially increased political control and a much larger role for specific international or national organisations in politics and society. In other words, some politicians may have strong incentives to piggyback increased overall political control of the economy onto standard environmental policy, which may be an effective way of reducing the electoral resistance to such control while benefitting special interests. As such, both the left and right in politics have interests in such regulation and weakened institutions. Although politicians and political parties occasionally blame each other, industrial special interests more politically aligned with right-wing parties may lobby for regulation to artificially protect their profitability just as it may be a specific left-wing project under the influence of labour unions to protect jobs in traditional sectors (cf., Aidt et al., 2018).

2.5. *The overall pattern*

In total, the full theoretical picture is distinctly muddled. It is possible to find theoretical arguments in order to defend almost any position on whether an economically free market economy or a state-controlled and politically regulated society are preferable. Yet, regardless of one's position, one would ideally want a political-economic system that places minimal epistemic demands on politicians and civil servants designing environmental policy. One would presumably also strongly prefer politically independent judiciaries and bureaucracies and effective constitutional limits on policymaking in order to avoid public choice problems (Buchanan and Tullock, 1962). How close the typical situation in most years is to such an ideal, and to which extent economic freedom is associated with dynamic development towards a low-emissions economy is eventually an empirical question, which I address in the rest of the paper.

3. Data and estimation strategy

While there are many dimensions to the debate about pollution, climate change and emissions, most political discussions – and certainly some of the fiercest discussions – centre on countries' emissions of CO_2. I therefore focus on the development over time in (the logarithm to) emissions of CO_2, measured in kilotons per inhabitant, which I derive from the World Development Indicators database (World Bank, 2023). From the same source, I derive data on the emissions of total greenhouse gases (which also includes all anthropogenic CH_4 sources, N_2O sources and F-gases).

In the choice of the main policy variable, I follow a long literature in employing the Economic Freedom of the World (EFW) dataset, which is published annually by the Fraser Institute (Gwartney et al., 2020). Economic freedom is defined on the basis of the belief that all "individuals have a right to choose – to decide how to use their time and talents to shape their lives" such that they are "economically free when they are permitted to choose for themselves and engage in voluntary transactions as long as they do not harm

[7] The latter case can exacerbate insider-outsider problems where unions create unemployment by only negotiation wages and labour contracts for those already in the labour market (Lindbeck and Snower, 2001).

the person or property of others. […] economically free individuals will be permitted to decide for themselves rather than having options imposed on them by the political process or the use of violence, theft, or fraud by others." (Gwartney et al., 2020, 1). The EFW index is therefore the most frequently used measure of the degree to which a society can be characterised as having a free market economy; Hall and Lawson (2014) and Lawson (2022) survey the large literature. The entire index, which is measured on a scale from 0 to 10, can be broken down into its five constituent parts: Size of government, Legal system and property rights, Sound money, Freedom to trade internationally, and Regulation. I follow a long series of studies in both testing the effects of the overall index as well as breaking it down into three parts, consisting of size of government, legal quality, and policy quality, which is an average of sound money, freedom to trade, and regulation. This may be important, as the size of government in particular is only weakly correlated with the remaining elements of the EFW index and legal quality is known to be particularly important, but the least changeable over time (Heckelman and Stroup, 2005; Sobel and Coyne, 2011; Rode and Coll, 2012). In the appendix, I also provide tests with the policy quality index disaggregated. Throughout, I follow the common terminology of the literature on economic freedom, although it must be emphasised that the legal quality indicator is often used outside of this literature as a common proxy for the rule of law or the broader concept of quality of governance.

In order to estimate an Environmental Kuznets Curve (cf., Dasgupta et al., 2002), I employ data on the logarithm to real, purchasing-power adjusted GDP per capita and its square from the Penn World Tables, Mark 9.1 (Feenstra et al., 2015). From the same source, I also employ the logarithm to the size of the population, as well as data on the total volume of trade in manufactured goods, as percent of GDP (cf., Rafiq et al., 2016). I keep the specification as parsimonious as possible in order not to introduce bad controls, as well as not to require additional data that would substantially reduce the sample size.[8] In a series of tests, I further restrict the sample to only democracies, defined in a minimalist way as countries with free and fair elections that *de facto* can lead to government change. The reason for restricting the sample is that a number of likely transmission mechanisms require some level of democracy to work. Such heterogeneity would not be captured by merely adding democracy to the specification as a control variable. The indicator used is Bjørnskov and Rode's (2020) update of the much-used dichotomous indicator from Cheibub et al. (2010).

In three sets of further tests, I add five additional variables. First, I provide tests adding urbanisation and the share of industry in GDP from the World Bank (2023). These variables have been related to the environmental Kuznets Curve in previous research, although one may arguably consider them as measures of transmission mechanisms (Dogan and Inglesi-Lotz, 2020). This would for example be the case if economic freedom affects the sectorial composition of the economy and thereby greenhouse gas emissions. Second, I add an environmental stringency index from the OECD (2016), which recent research finds is associated with lower levels of pollution (Graafland and Verbruggen, 2022). Third, I add the human capital index from the Penn World Tables and life expectancy at birth from the World Bank (2023) in order to control for human capital influences suggested by previous research, which may also be associated with economic freedom (cf., Lawson et al., 2020).

The combination of these data yields an unbalanced panel of up to 155 countries observed in consecutive, non-overlapping five-year periods beginning in 1975 and ending in 2015; all data are summarised in Table 1. In the additional tests, the dataset is substantially smaller. With the data, I estimate an EKC, i.e. the effect of the logarithm to GDP per capita and its square, using a standard OLS estimator with period and country fixed effects, and standard errors clustered at the country level. This implies that all estimates are identified by period-to-period changes across five years, which reduces most concerns related to multi-collinearity and proxies for culture or geography. As both emissions of CO_2 and total greenhouse gases and GDP per capita are measured in logs, the estimates can be interpreted as medium-to long-run quasi-elasticities.[9] In subsequent tests, in addition to entering the EFW index as a linear control variable, I also interact it with the Kuznets Curve, that is, with the logarithm to GDP per capita and its square. As such, these tests allow for estimating the central question of this paper: whether economic freedom affects the *transition* towards a low-emissions economy, which would be observable as a shift in the shape and position of the Kuznets curve. I do so using both the full EFW index as well as three decomposed factors, which informs about which of the many theoretically possible mechanisms may exist and be particularly strong. In an additional horse race test in the appendix, I add interactions with two of the three EFW indicators, as they may not be perfectly separable.

Although I throughout the paper refer to effects and use causal language, it may be possible that the emissions of greenhouse gases could affect single economies in the long run. It may *a priori* appear highly unlikely, and even the IPCC (2014) assesses that the global income loss of unmitigated climate change is a few percent over a period of 80 years. Yet, emissions could in principle affect the level of economic freedom or reflect factors that might affect it. Although there is no practical way of alleviating this potential problem, its consequences are worth noting when interpreting the estimates in the following.

The main mechanism through which greenhouse gas emissions could affect components of economic freedom is through affecting regulatory politics in relatively wealthy societies. High levels of emissions, either in absolute terms or compared to other relatively rich countries, may cause popular or industry demands for political action. These demands may come in terms of additional market

[8] Ideally, one would include measures of the type of energy policy, energy taxes and subsidies, and specific regulations, as well as a number of other specific factors. However, the availability of such data is very limited, their inclusion is therefore infeasible, and the earlier literature is markedly mixed (de Bruyn and Heintz, 2000). Bad controls would, for example, include production types of energy and levels of technology, as economic freedom could arguably make specific types more profitable and thus make the production mix a transmission mechanism of the emissions of greenhouse gases.

[9] The economic freedom data are only available every five years before 2000, necessitating the adoption of longer periods than annual data. However, this comes with the benefit that the estimates can be interpreted as medium-run equilibrium effects instead of a mix between longer-run effects and business cycle fluctuations.

Table 1
Descriptive statistics.

Variable	Mean	Standard deviation	Observations
CO_2 emissions per capita (log)	0.495	1.729	1216
Total greenhouse gases (log)	8.654	1.057	1142
Log GDP	8.907	1.260	1356
Log population	2.081	1.706	1356
Trade volume	0.529	0.509	1356
Urbanisation	52.663	23.714	1449
Industry share of GDP	28.813	12.539	1153
Environmental stringency	0.733	0.847	294
Economic Freedom	6.164	1.314	1098
Size of government	5.893	1.569	1136
Legal quality	5.189	1.896	1061
Policy quality	6.506	1.636	1160
Sound money	7.108	2.136	1158
Freedom to trade	6.245	2.127	1109
Regulation	6.256	1.379	1097

regulation or more direct government control of production. As such, through a policy mechanism, which would only appear relevant and enforceable in relatively wealthy societies, higher levels of emissions would become negatively associated with legal quality or the policy quality component of economic freedom. What would appear as the most relevant mechanism biasing estimates in the following thus entails – if relevant at all – that the implied EKC moves up and to the right.

4. Empirical results

Before turning to the estimates, Fig. 1 provides an impression of the data. The figure plots the change in CO_2 emissions per capita between 1990 and 2015 for countries in four equally sized groups: the quartile of countries with the lowest average EFW index across the period, the second quartile (the low-mid EFW), the third quartile (the mid-high EFW), and the quartile with the highest average level of economic freedom during the 25-year period.

The figure clearly illustrates how the third and fourth quartiles differ from the rest. In the former group, which includes economically successful lower and middle-income countries such as Botswana, Cape Verde, Mexico and South Africa, emissions on average increased by almost an entire tonne per capita. In the latter group, that for example includes Denmark, the United Kingdom, and Singapore, but also middle-income countries like Chile, Costa Rica and Panama, emissions decreased by on average 0.7 tonnes of CO_2. While performance in the third quintile is very diverse and its emissions development is only statistically weakly worse than performance in the first and second quintiles ($p < 0.09$), the fourth quintile is substantially and significantly different from the other groups ($p < 0.01$). As such, the simple long-run profiles exemplified in Fig. 1 indicate that a greenhouse gas Kuznets Curve may exist and depend on the level of economic freedom.

4.1. Main results

With these simple differences in mind, I next proceed to the formal estimates, beginning with the simple, linear tests in Table 2; the implied Kuznets Curve is illustrated in appendix figure A1. Overall, the estimates suggest that population growth leads to higher CO_2 emissions per capita, although this effect appears driven by the inclusion of autocracies in columns 1 and 2. The results also suggest no clear, general effects of economic freedom. Conversely, while the estimates of GDP and GDP squared provide evidence of an EKC, a glance at the four sets of estimates makes it obvious that there is substantially more curvature in the democratic subsample. Yet, the

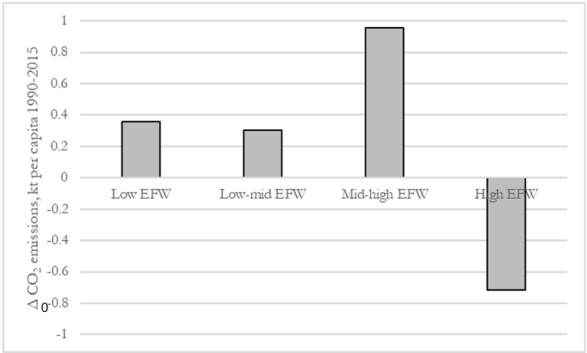

Fig. 1. Changes in CO_2 emissions, 1990–2015, four EFW categories.

Table 2
Simple results, CO_2 emissions.

	All countries		Democracies only	
	1	2	3	4
Log GDP	1.748** (0.813)	1.877** (0.864)	3.839*** (0.839)	4.027*** (0.845)
Log GDP squared	−0.056 (0.046)	−0.064 (0.049)	−0.166*** (0.044)	−0.177*** (0.044)
Log population	0.411** (0.172)	0.467** (0.183)	0.308 (0.235)	0.308 (0.245)
Trade volume	−0.018 (0.058)	0.014 (0.054)	0.009 (0.123)	0.043 (0.123)
Economic Freedom	0.019 (0.024)	0.027 (0.028)	−0.001 (0.021)	0.008 (0.025)
Period FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	1006	899	558	507
Countries	155	139	103	95
Within R squared	0.390	0.389	0.433	0.439
F statistic	11.51	10.64	8.68	7.71

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level. In columns 2 and 4, the ten largest oil and gas producers are excluded.

Table 3
Conditional results.

	CO_2, all countries		CO_2, democracies only		Total greenhouse gases	
	1	2	3	4	5	6
Log GDP	−2.099 (1.674)	−2.056 (1.989)	−2.511 (1.715)	−5.517*** (2.111)	−0.838 (1.919)	−0.762 (1.953)
Log GDP squared	0.175 (0.100)	0.169 (0.122)	0.176* (0.096)	0.318*** (0.121)	0.103 (0.109)	0.096 (0.110)
Log population	0.455*** (0.153)	0.514*** (0.176)	0.377* (0.193)	0.248 (0.277)	0.318 (0.225)	0.324 (0.236)
Trade volume	0.013 (0.057)	0.034 (0.056)	−0.044 (0.084)	0.003 (0.083)	0.015 (0.121)	0.051 (0.121)
Economic Freedom	−2.492*** (0.890)	−2.620*** (0.979)	−1.573* (0.926)	−5.804*** (1.532)	−2.564* (1.421)	−2.831* (1.469)
GDP * Economic Freedom	0.597*** (0.213)	0.622*** (0.239)	0.382* (0.211)	1.254*** (0.343)	0.599** (0.302)	0.653** (0.311)
GDP squared * Economic Freedom	−0.035*** (0.013)	−0.036** (0.015)	−0.023* (0.012)	−0.068*** (0.019)	−0.035** (0.016)	−0.037** (0.017)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1006	899	885	434	558	507
Countries	155	139	143	88	103	95
Within R squared	0.417	0.414	0.135	0.170	0.449	0.455
F statistic	13.29	12.20	7.91	5.38	8.91	7.95

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level. In columns 2, 4 and 6, the ten largest oil and gas producers are excluded.

estimates in column 4, which excludes both autocracies and the ten largest oil producers in the sample, still imply an average turning point of the EKC of approximately 80,000 USD per capita. In other words, only the very richest societies in the world appear to be at a point of economic development at which their emissions begin to decrease.

However, the linear estimate of economic freedom in Table 2 is only likely to capture static effects of changing policies consistent with a status of economic freedom. Yet, arguments both against and in favour of freedom in section 2 suggest that its effects are

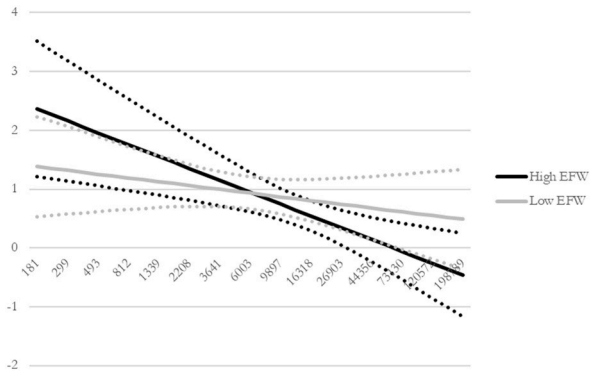

Fig. 2. Marginal effects of increasing GDP per capita, high and low EFW scores.

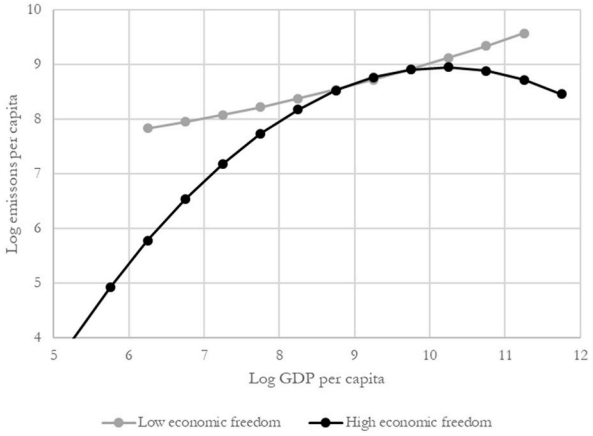

Fig. 3. Implied Kuznets curves.

dynamic, i.e. that economic freedom affects the transition patterns inherent in any Kuznets Curve. In Tables 3 and 4 I interact economic freedom with GDP and GDP squared, and thereby allow it to affect the shape and position of the curve. The tables also include tests for emissions of total greenhouse gases.

The main results in the table must be interpreted with care, as the estimates of both GDP, GDP squared and economic freedom cannot be interpreted on their own, but only as conditional estimates (Brambor et al., 2006). However, the interactions indicate that for each point of change in economic freedom, both the upward and downward sloping parts of the CO_2 Kuznets Curve become steeper. They also indicate that the top point of the curve – i.e. the level of economic development at which point emissions typically start to decrease – occurs significantly earlier the higher is the level of economic freedom.

In other words, economic freedom both implies more curvature and shifts the EKC to the left. Evaluated at a level of economic freedom of 8, i.e. for the approximately ten percent freest countries in recent years, the estimates imply a turning point at about 63,000 USD and a point at which GDP is no longer significantly positive at approximately 35,000 USD for CO_2 emissions. Fig. 2 illustrates the main difference by depicting the marginal effect of increasing GDP per capita, evaluated around the 90th percentile of the EFW index,

Table 4
Emissions, components of economic freedom.

	Indicator: economic Freedom		Indicator: size of government		Indicator: legal quality		Indicator: policy quality	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	−0.762	−5.517***	6.256***	0.169	−0.636	−5.089***	−1.325	−5.629***
	(1.953)	(2.111)	(1.635)	(1.660)	(1.442)	(1.615)	(1.762)	(1.871)
Log GDP squared	0.096	0.318***	−0.307***	0.001	0.091 (0.077)	0.309***	0.127 (0.100)	0.327***
	(0.110)	(0.121)	(0.090)	(0.091)		(0.095)		(0.105)
Log population	0.324	0.248 (0.277)	0.275 (0.239)	0.249	0.529***	0.122 (0.285)	0.314 (0.239)	0.164 (0.271)
	(0.236)			(0.273)	(0.194)			
Trade volume	0.051	0.003 (0.083)	0.043 (0.114)	−0.051	0.013 (0.081)	−0.063	0.056 (0.120)	0.008 (0.075)
	(0.121)			(0.083)		(0.096)		
EFW indicator	−2.831*	−5.804***	1.314 (1.031)	−1.194	−2.570**	−4.968***	−3.116***	−5.473***
	(1.469)	(1.532)		(1.229)	(1.100)	(1.371)	(1.191)	(1.358)
GDP * EFW	0.653**	1.254***	−0.317	0.243	0.615***	1.121***	0.708***	1.183***
indicator	(0.311)	(0.343)	(0.228)	(0.271)	(0.235)	(0.314)	(0.256)	(0.295)
GDP squared *	−0.037	−0.068***	0.019 (0.012)	−0.012	−0.036***	−0.063***	−0.039***	−0.064***
EFW indicator	(0.017)	(0.019)		(0.015)	(0.013)	(0.018)	(0.014)	(0.016)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	507	434	506	438	498	420	507	440
Countries	95	88	95	88	95	88	95	88
Within R squared	0.455	0.170	0.451	0.129	0.521	0.182	0.463	0.183
F statistic	7.95	5.38	7.09	4.78	11.52	6.90	7.86	6.10
Implied GDP per capita *at turning point at level of economics freedom*								
10th percentile	>250,000	>250,000	45,337	197,522	>250,000	–	>250,000	>250,000
Median	112,396	37,286	74,047	91,307	220,441	306,541	99,827	40,096
90th percentile	65,524	25,255	135,418	68,032	46,775	22,881	57,298	25,991

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

i.e. at high economic freedom, and at the low level of the 10th percentile. The figure shows how, despite starting at a higher impact of economic development, the marginal effects of development decrease substantially faster in an economically free society. Fig. 3 depicts the same pattern in a different way by plotting the two CO_2 Kuznets Curves implied by the estimates.

However, while the political focus in recent years has been on CO_2 as the leading – and occasionally only – indicator of economic effects on climate change, several other types of emissions may be relevant. Columns 5 and 6 therefore report equivalent results for the total emissions of greenhouse gases, which generally are similar to those in columns 1–4. The estimates show that the EKC for total greenhouse gases is similar to that for CO_2 alone, but with a substantially earlier turning point. The results in column 6 suggest that at high levels of economic freedom (an index of 8), the emissions of greenhouse gases in general start decreasing from a GDP level of approximately 25,000 USD. This turning point occurs at significantly higher levels of GDP the less economically free society is.

4.2. Distinguishing between elements of economic freedom

However, as several studies show, it is often necessary to distinguish between elements of the EFW index. Doing so, as reported in Table 4, shows that these differences are not driven by the size of government, but are somewhat stronger and visibly more precisely estimated with the subcomponent that measures the quality of the legal system (cf., Rode and Coll, 2012). Interpreting the estimates symmetrically, as recommended by Brambor et al. (2006), using this component yields an estimated turning point of the CO_2 Kuznets Curve about 66,000 USD, close to the present level of economic development of parts of Northern Europe and North America, when evaluating the EKC at the 90th percentile of economic freedom.[10] Similarly, for total greenhouse gas emissions, the results in Table 4 specific to legal quality indicate a GDP turning point about 25,000 USD.[11] Similarly, using policy quality instead of legal quality also yields evidence for an EKC although somewhat flatter with lower (but still high) turning points at median levels of policy quality and slightly higher turning points at high levels of policy quality, compared to those obtained with legal quality. The findings thus document the existence of an EKC for CO_2 and other greenhouse gases, which becomes substantially more pronounced and with lower turning points the more economically free a society is. The lowest implied turning points appear for legal quality, for which they are about 47,000 and 23,000 USD, respectively, as evaluated for countries around the 90th percentile of legal quality (or roughly the 20 percent with the best rule of law).

However, a potential problem is that the components of economic freedom may not be entirely separable. The correlations between size of government and legal quality, and with policy quality, are −0.40 and 0.03, in democracies, and the correlation between legal quality and policy quality is 0.55; the respective correlations between period-to-period changes in the three variables are −0.10, 0.12, and 0.22. As such, with a fixed effects specification the direct effects should be easily separable due to the low correlations between period-to-period changes. Yet, the shape of the EKC is defined by the *levels* of economic freedom, which creates a potential problem.

I explore this problem in a set of horse race tests, reported in the appendix table A1; these tests also to some extent capture a set of potential omitted variables, if the estimated effects of one component are biased by factors inherent in other components of economic freedom. The horse race reveals that the addition of the size of government does not clearly affect estimates of legal quality or policy quality. Conversely, including both legal quality and policy quality in the same regression has the effect of reducing the estimated interactions between GDP and legal quality by about a third, and those between GDP and policy quality by about half in the CO_2 regressions. The comparative results for regression with the full greenhouse gas emissions as dependent variable instead shows unchanged effects of legal quality, but yield somewhat weaker and insignificant evidence of clear moderating effects of policy quality.

4.3. Robustness tests

Overall, a set of further tests also shows that the main findings are robust. These tests, documented in the appendix, first indicate that when separating the policy quality index into its three component parts, regulation seems to be somewhat weaker related to CO_2 emissions than sound money and the freedom to trade internationally, but if anything more strongly associated with overall greenhouse gas emissions (table A2). Second, adding urbanisation and the share of industry in GDP as proxies for the economic structure of society in table A3 does to some degree affect the main findings although the latter variable somewhat restricts the sample size. The additional results in table A3 suggest that at least some effects of economic freedom run through its consequences for economic structure. Likewise, when adding a human capital index and life expectancy in table A4 changes no qualitative findings as the marginal effects remain very similar to those in Table 4. Finally, adding the OECD's environmental stringency index in table A5, and with an

[10] These results also indicate that legal quality is significantly *positively* associated with CO2 emissions at intermediate levels between 4000 and 10,000 USD.

[11] In addition to these results, an online appendix explores a similar Kuznets Curve for the transition towards the use of renewable energy. These findings confirm the existence of a general transition, as the use of renewable energy starts increasing from an income level around 26,000 USD per capita in economically very free societies, but at much higher levels of income in less free societies. It is thus also unlikely that the pattern identified in Table 3 is created by shifts away from CO2 emissions to other greenhouse gases or towards the use of other forms of non-renewable energy that are less politically visible. Similar to the results in Table 4, the appendix results suggest that the Kuznets Curve is most precisely estimated when using the component capturing legal quality, which also yields the lowest implied turning points of the curves (21,000 USD in democracies). The estimates In Table 4 also indicate a role for the size of government with rich countries with large government sectors moving towards more renewable energy. However, it must be emphasised that the only countries with sufficiently large government sectors and incomes to fit the combination for which this is significant are the three Scandinavian countries.

interaction with GDP per capita and its square, in table A6, also changes things. While there are indications of some interaction with the stringency index, all estimates in table A6 in particular are very noisy. This should not come as a surprise, as the environmental stringency index is weakly correlated with any of the components of economic freedom but the addition limits the sample to only 42 countries and approximately half the observations as in Table 4.[12]

Further tests (not shown) illustrate that all main results are robust to for example excluding specific types of autocracies instead of all non-democratic regimes, excluding the very poorest countries, and excluding post-communist countries (cf., Bjørnskov, 2018). The main results are also robust to, for example, controlling for whether countries have ratified the Kyoto Protocol. As outlined in the final section, these results thus may also have important policy implications.

5. Conclusions

One of the most hotly debated questions in international politics as well as most Western countries is whether and how to achieve a transition to a low-emissions society that economises on the use of non-renewable resources and pollutes less. Unfortunately, it is a discussion where economic and political-economic theory provides no clear answers or insights. Depending on one's political beliefs and sensibilities, it is possible to pick almost any position on whether government intervention is good, bad or irrelevant for the development towards less pollution and a low-carbon economy. As argued in section 2, economic theory *per se* is not helpful for drawing firm implications.

However, employing a large panel dataset covering up to 155 countries observed in five-year periods since 1975 allows me to estimate Environmental Kuznets Curves for the emissions of CO_2 and other greenhouse gases. Keeping in mind that causality must remain an open question, all analyses here provide clear results. Allowing the shape and position of the EKC to depend on economic freedom indicates that transitions towards lower emissions occur faster and at lower levels of average income in economically free societies. The most precise estimates suggest that rich, economically free democracies such as Australia, Canada, the US and large parts of Northern Europe may already have passed the turning point of the CO_2 Kuznets curve. Focusing on the emission of all greenhouse gases, estimates suggest that further economic development is likely to lead to reduced emissions in most Western societies, as long as their policies are consistently economically free. Overall, although the theoretical considerations are decidedly mixed, the empirical evidence is not. The EKC is typically situated to the left in economically free societies, indicating earlier adoption of clean technology and faster transition towards a low-emissions society.

However, while the estimates are clear and robust, they must be interpreted with care. First, causality may be a problem if greenhouse gas emissions either affect economic development directly or affect basic economic policies and institutions. One could, for example, easily imagine that growing greenhouse gas emissions, combined with growing awareness of the problem, would cause some governments to introduce substantial environmental regulation and perhaps also direct control of parts of the economy. To the extent that such regulation registers in the economic freedom indices, this type of problem would result in biased estimates, although the bias would work against the present findings. Although there is very little evidence of how economic freedom is related to emissions, the few existing studies suggest that societies that embrace free markets tend to increase physical capital with less damage to environmental sustainability and lower pollution (Wood and Herzog, 2014; de Soysa, 2022). The strong persistence of legal quality in particular also indicates that the results pertaining to this component of economic freedom are unlikely to be strongly biased (cf., Sobel and Coyne, 2011).

Causality could also be a problem if emissions directly affect GDP per capita or one of its main components. However, while there is preciously little evidence of such a relation, implying that one should not reject that this may be a problem, most of the climate literature places any direct effects of climate change on economic performance in the future. As such, it is unlikely – although not impossible – that causality is a problem for the emissions-GDP relation identified in this paper. This also means that even though estimates of the direct effects of economic freedom may be biased, the interaction between the EKC and economic freedom remains approximately unbiased (cf., Nizalova and Murtazashvili, 2016).

Second, a longer literature explores the causality between GDP and institutional quality. Overall, this literature finds that causality predominantly runs from institutional quality and economic freedom to long-run economic growth while even the sign of the reverse causal direction remains disputed (cf., Dawson, 2003; Justesen, 2008; Bjørnskov, 2016). This therefore implies that the estimates in this paper may slightly underestimate the speed of the transition in economically free societies, as economic freedom not only changes the EKC but also contributes to faster economic growth and productivity increases (Hall and Lawson, 2014; Bjørnskov and Foss, 2016).

Third, the effects argued for in this paper likely arise from economic freedom producing more innovation, more entrepreneurship commercialising new innovation, and more productivity and positive structural change. This is a common finding in much of the literature on economic freedom, although not under all conditions (see, e.g., de Haan and Sturm, 2024; Bylund et al., 2024). One could therefore imagine situations in which economic freedom contributes to new research and innovation, but not to research or innovation directed towards reducing emissions and resource use. This is, indeed, occasionally an argument in favour of political control of research and industry (e.g., Mazzucato, 2013). Yet, history suggests that the impact of decentralised research efforts tends to be substantially larger than that controlled by government (Mokyr, 2009). Likewise, studies of both university research in the US states as well as academic freedom across the world in recent decades indicate that societies in which government does not attempt to control research processes or the dissemination of knowledge are substantially more innovate and productive (Aghion et al., 2010; Berggren

[12] Although one should not conclude too much from estimates that are inevitably noisy when adding two sets of double interactions, the findings in table A6do indicate that the turning point of the EKC shifts to the left with both higher environmental stringency and higher legal quality.

and Bjørnskov, 2022).

Finally, further research is needed in order to exploit if particular cultural traits or other institutional characteristics help or hinder the effects of economic freedom on green innovation and a transition towards lower emissions. Studies in management science for example suggest that a cultural long-term orientation interacts with economic freedom in affecting the (somewhat nebulous) concept of corporate socially responsible investment at the firm level (Graafland, 2019; Graafland and Noorderhaven, 2020). Dutta and Sobel (2021) likewise find that economic freedom may interact with a culturally defined fear of failure or of losing face in affecting long-run innovation. However, democracy may exert a detrimental effect, at least in poor and middle-income societies, as a significant share of voters desires material consumption and protection of existing jobs, which could in principle both affect a green transition and labour market regulation. Conversely, to the extent that environmental quality is a superior good when income increases, voters in relatively wealthy countries may be particularly prone to supporting a green transition.

Overall, despite these caveats, this paper provides one of the first studies to document that economic freedom affects the EKC and thus has consequences for the transition towards less pollution and lower greenhouse gas emissions. If the findings can be replicated in other studies, they suggest that a hands-off approach to overall policy-making eventually results in substantially lower emissions and an earlier transition towards a low-emissions path (cf., Aidt et al., 2018). Conversely, although most democratically elected governments today proclaim a better environment as a central political aim, interventionist governments are likely to achieve the opposite.

Table A1
Emissions, horse race tests

	Two indicators		Two indicators		Two indicators		Three indicators	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	1.942	−3.853**	0.817 (1.717)	−5.155**	−2.135	−5.760***	0.083	−5.052***
	(1.477)	(1.943)		(2.038)	(1.874)	(1.739)	(1.701)	(1.926)
Log GDP squared	−0.056	0.240**	0.007 (0.097)	0.302***	0.171*	0.339***	0.046	0.302***
	(0.079)	(0.114)		(0.112)	(0.103)	(0.102)	(0.093)	(0.113)
Size of government	1.773*	1.135 (0.724)	2.151*	0.989 (1.019)			2.090*	1.656**
	(1.007)		(1.271)				(1.244)	(0.815)
Legal quality	−2.723**	−5.171***			−1.726	−4.731***	−1.558	−4.730***
	(1.193)	(1.341)			(1.166)	(1.542)	(1.160)	(1.471)
Policy quality			−3.524**	−5.760***	−2.115*	−1.537	−2.634*	
			(1.396)	(1.231)	(1.145)	(1.249)	(1.362)	
GDP * size of gov.	−0.418*	−0.259	−0.504*	−0.224			−0.488*	−0.363*
	(0.218)	(0.164)	(0.278)	(0.227)			(0.267)	(0.184)
GDP squared * size of gov.	0.024**	0.015 (0.009)	0.029*	0.013 (0.013)			0.028*	0.019*
	(0.012)		(0.015)				(0.014)	(0.010)
GDP * legal quality	0.651**	1.166***			0.426*	1.075***	0.387	1.069***
	(0.253)	(0.305)			(0.252)	(0.354)	(0.247)	(0.337)
GDP squared * legal quality	−0.038**	−0.065***			−0.026*	−0.060***	−0.023*	−0.059***
	(0.013)	(0.017)			(0.014)	(0.020)	(0.013)	(0.019)
GDP * policy quality			0.814***	1.255***	0.449*	0.296 (0.269)	0.579**	−2.348*
			(0.299)	(0.270)	(0.246)		(0.290)	(1.285)
GDP squared * policy quality			−0.047***	−0.068***	−0.024*	−0.014	−0.032**	0.480*
			(0.016)	(0.015)	(0.013)	(0.014)	(0.015)	(0.275)
Period *FE*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	496	418	506	438	497	420	496	418
Countries	95	88	95	88	95	88	95	88
Within R squared	0.540	0.191	0.485	0.194	0.533	0.195	0.553	0.206
F statistic	10.41	7.81	7.93	7.14	10.26	6.96	9.79	9.97

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded. All regressions also include the log to population and trade volumes.

Table A2
Emissions, decomposing policy quality

	Indicator: policy quality		Indicator: sound money		Indicator: freedom to trade		Indicator: regulation	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	−1.325	−5.629***	1.048	−3.013	0.557 (1.263)	−1.296	0.458	−5.264***
	(1.762)	(1.871)	(1.365)	(2.061)		(1.380)	(2.085)	(1.725)
Log GDP squared	0.127 (0.100)	0.327***	−0.008	0.188 (0.114)	0.022 (0.075)	0.093 (0.079)	0.025	0.302***
		(0.105)	(0.077)				(0.111)	(0.098)

(*continued on next page*)

Table A2 (*continued*)

	Indicator: policy quality		Indicator: sound money		Indicator: freedom to trade		Indicator: regulation	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log population	0.314 (0.239)	0.164 (0.271)	0.333 (0.243)	0.209 (0.281)	0.224 (0.239)	0.212 (0.276)	0.262 (0.245)	0.259 (0.278)
Trade volume	0.056 (0.120)	0.008 (0.075)	0.056 (0.122)	−0.007 (0.085)	0.038 (0.113)	−0.025 (0.081)	0.081 (0.119)	0.018 (0.083)
EFW indicator	−3.116*** (1.191)	−5.473*** (1.358)	−1.395** (0.678)	−2.403** (1.123)	−2.101** (0.834)	−2.713*** (0.842)	−2.166 (1.474)	−5.201*** (1.218)
GDP * EFW indicator	0.708*** (0.256)	1.183*** (0.295)	0.323** (0.149)	0.538** (0.243)	0.482** (0.185)	0.589*** (0.187)	0.486 (0.309)	1.128*** (0.275)
GDP squared * EFW indicator	−0.039*** (0.014)	−0.064*** (0.016)	−0.018** (0.008)	−0.029** (0.013)	−0.027*** (0.010)	−0.032*** (0.010)	−0.028* (0.016)	−0.061*** (0.016)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	507	440	507	440	505	436	507	433
Countries	95	88	95	88	95	88	95	88
Within R squared	0.463	0.183	0.449	0.138	0.460	0.164	0.467	0.182
F statistic	7.86	6.10	8.46	4.08	9.91	5.29	8.48	6.70
Implied GDP per capita *at turning point at level of economics freedom*								
10th percentile	>250,000	>250,000	>250,000	–	>250,000	215,468	>250,000	>250,000
Median	99,827	40,096	103,097	154,742	98,661	44,829	102,875	39,913
90th percentile	57,298	25,991	71,076	47,487	63,899	32,431	62,574	22,848

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

Table A3
Emissions, additional variables capturing economic structure

	Indicator: economic Freedom		Indicator: size of government		Indicator: legal quality		Indicator: policy quality	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	−0.887 (2.427)	−5.044** (2.081)	5.718*** (1.659)	−0.522 (1.813)	−0.885 (1.493)	−4.454*** (1.544)	−1.385 (2.188)	−4.745** (2.184)
Log GDP squared	0.109 (0.142)	0.300** (0.119)	−0.279 (0.092)	0.047 (0.101)	0.104 (0.082)	0.277*** (0.086)	0.133 (0.128)	0.283** (0.128)
Log population	0.488* (0.272)	0.389 (0.251)	0.463* (0.254)	0.425 (0.324)	0.725*** (0.204)	0.102 (0.283)	0.458 (0.277)	0.330 (0.241)
Trade volume	−0.033 (0.101)	−0.054 (0.097)	−0.016 (0.098)	−0.079 (0.095)	0.001 (0.094)	−0.124 (0.097)	−0.026 (0.097)	−0.043 (0.093)
Urbanisation	−0.001 (0.007)	−0.004 (0.006)	0.002 (0.006)	−0.002 (0.006)	0.001 (0.005)	0.005 (0.008)	−0.001 (0.007)	−0.004 (0.005)
Industry share of GDP	0.004 (0.003)	−0.003 (0.004)	0.004 (0.003)	−0.006 (0.006)	0.005 (0.003)	−0.000 (0.003)	0.004 (0.003)	−0.005 (0.005)
EFW indicator	−2.073 (1.739)	−4.729*** (1.474)	1.866* (1.041)	−0.864 (1.147)	−2.119* (1.219)	−3.847*** (1.319)	−2.519* (1.439)	−4.332*** (1.305)
GDP * EFW indicator	0.492 (0.384)	1.025*** (0.319)	−0.441* (0.231)	0.176 (0.252)	0.509* (0.264)	0.873*** (0.303)	0.576* (0.318)	0.934*** (0.281)
GDP squared * EFW indicator	−0.029 (0.021)	−0.056*** (0.017)	0.025** (0.013)	−0.009 (0.014)	−0.029** (0.014)	−0.049*** (0.017)	−0.033* (0.018)	−0.050*** (0.015)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	453	367	452	370	445	355	453	371
Countries	92	85	92	85	92	85	92	85
Within R squared	0.527	0.191	0.525	0.165	0.537	0.197	0.535	0.210
F statistic	7.88	7.12	7.09	7.36	13.63	8.03	8.70	9.02
Implied GDP per capita *at turning point at level of economics freedom*								
10th percentile	>250,000	>250,000	68,215	–	>250,000	–	>250,000	>250,000
Median	>250,000	184,484	222,215	>250,000	>250,000	>250,000	>250,000	129,782
90th percentile	217,805	57,777	>250,000	>250,000	105,545	45,042	119,578	50,600

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

Table A4
Emissions, additional variables capturing human capital

	Indicator: economic Freedom		Indicator: size of government		Indicator: legal quality		Indicator: policy quality	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	−2.037	−5.055**	6.336***	0.265	−0.777	−4.923***	−2.672	−5.463***
	(2.209)	(2.336)	(1.713)	(1.565)	(1.556)	(1.784)	(1.947)	(1.876)
Log GDP squared	0.158	0.287**	−0.319***	−0.013	0.098 (0.084)	0.299***	0.191*	0.313***
	(0.124)	(0.136)	(0.094)	(0.085)		(0.106)	(0.109)	(0.106)
Log population	0.328	0.223 (0.278)	0.265 (0.232)	0.212	0.481**	0.122 (0.303)	0.310 (0.219)	0.130 (0.275)
	(0.218)			(0.269)	(0.206)			
Trade volume	−0.074	−0.012	−0.062	−0.048	−0.020	−0.076	−0.076	−0.007
	(0.091)	(0.092)	(0.083)	(0.089)	(0.087)	(0.098)	(0.088)	(0.086)
Human capital	−0.065	0.203 (0.231)	0.161 (0.155)	0.442**	0.040 (0.160)	0.104 (0.289)	−0.071	0.221 (0.219)
	(0.158)			(0.216)			(0.154)	
Life expectancy	0.016*	0.003 (0.010)	0.011 (0.009)	0.002	0.006 (0.009)	−0.005	0.020**	0.007 (0.009)
	(0.009)			(0.010)		(0.010)	(0.009)	
EFW indicator	−3.886**	−5.451***	1.544 (1.069)	−0.852	−2.619**	−4.789***	−4.234***	−5.325***
	(1.721)	(1.728)		(1.218)	(1.191)	(1.519)	(1.366)	(1.421)
GDP * EFW indicator	0.867**	1.169***	−0.377	0.159	0.625**	1.084***	0.933***	1.144***
	(0.362)	(0.392)	(0.236)	(0.269)	(0.254)	(0.351)	(0.291)	(0.312)
GDP squared * EFW indicator	−0.048**	−0.063***	0.022*	−0.007	−0.037***	−0.061***	−0.051***	−0.061***
	(0.019)	(0.022)	(0.013)	(0.015)	(0.014)	(0.020)	(0.016)	(0.017)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	483	423	482	427	474	409	483	429
Countries	86	84	86	84	86	84	86	84
Within R squared	0.527	0.178	0.523	0.149	0.534	0.188	0.540	0.194
F statistic	8.61	6.26	7.01	5.96	11.11	6.74	8.83	8.07
Implied GDP per capita *at turning point at level of economics freedom*								
10th percentile	>250,000	>250,000	35,121	58,634	>250,000	–	>250,000	>250,000
Median	81,588	32,543	62,948	63,907	222,078	>250,000	70,890	36,038
90th percentile	49,625	23,686	134,557	66,491	45,547	21,894	43,835	24,625

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

Table A5
Emissions, adding environmental policy stringency

	Indicator: economic Freedom		Indicator: size of government		Indicator: legal quality		Indicator: policy quality	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	2.598	1.092	4.636***	3.470**	−0.752	−7.275	1.660	1.417
	(2.568)	(4.389)	(1.459)	(1.624)	(2.193)	(6.264)	(2.961)	(3.112)
Log GDP squared	−0.123	−0.075	−0.234***	−0.183**	0.086	0.433	−0.067	−0.095
	(0.144)	(0.242)	(0.078)	(0.083)	(0.124)	(0.361)	(0.159)	(0.171)
Log population	0.560***	0.026	0.526***	−0.049	0.610***	0.041	0.559***	0.049
	(0.189)	(0.327)	(0.190)	(0.371)	(0.215)	(0.349)	(0.200)	(0.308)
Trade volume	−0.017	−0.077	0.009 (0.089)	−0.067	−0.041	−0.112	−0.030	−0.083
	(0.090)	(0.132)		(0.133)	(0.094)	(0.136)	(0.092)	(0.125)
Environmental stringency	−0.034	0.049	−0.019	0.052 (0.088)	−0.022	0.070	−0.032	0.045
	(0.024)	(0.100)	(0.020)		(0.024)	(0.092)	(0.024)	(0.094)
EFW indicator	−1.946	−2.836	0.016 (1.449)	0.565 (2.971)	−2.525	−6.184	−2.156	−2.583
	(1.775)	(4.045)			(1.570)	(4.679)	(2.179)	(2.897)
GDP * EFW indicator	0.339	0.510	−0.087	−0.163	0.568	1.392	0.409	0.459
	(0.372)	(0.872)	(0.302)	(0.617)	(0.346)	(1.067)	(0.444)	(0.609)
GDP squared * EFW indicator	−0.015	−0.022	0.008 (0.016)	0.011 (0.032)	−0.032*	−0.078	−0.019	−0.019
	(0.019)	(0.047)			(0.019)	(0.060)	(0.023)	(0.032)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	231	189	231	189	231	189	231	189
Countries	42	42	42	42	42	42	42	42
Within R squared	0.546	0.081	0.573	0.077	0.533	0.126	0.537	0.089
F statistic	14.71	5.60	48.58	4.36	31.57	1.86	15.08	5.66
Implied GDP per capita *at turning point at level of economics freedom*								
10th percentile	58,206	18.604	44,632	23,771	>250,000	–	75,171	16,449
Median	61,797	23,901	80,874	41,712	>250,000	>250,000	65,607	23,112
90th percentile	63,797	27,011	142,563	79,822	65,159	21,678	62,189	26,547

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

Table A6
Emissions, adding environmental policy stringency with interaction

	Indicator: size of government		Indicator: legal quality		Indicator: policy quality	
	CO_2	All greenhouse	CO_2	All greenhouse	CO_2	All greenhouse
Log GDP	5.330*** (1.089)	3.323** (1.429)	−0.099 (2.348)	−8.663 (6.914)	3.706 (3.399)	2.175 (2.664)
Log GDP squared	−0.269*** (0.058)	−0.179** (0.073)	0.049 (0.131)	0.507 (0.397)	−0.173 (0.180)	−0.133 (0.147)
Log population	0.617*** (0.212)	−0.004 (0.355)	0.656*** (0.235)	−0.069 (0.407)	0.613*** (0.215)	0.061 (0.312)
Trade volume	−0.028 (0.081)	−0.139 (0.148)	−0.065 (0.089)	−0.154 (0.138)	−0.052 (0.088)	−0.110 (0.133)
Environmental stringency	−8.035** (3.901)	−6.454 (8.416)	−2.963 (4.458)	6.160 (7.429)	−9.448* (5.130)	−6.268 (6.758)
GDP * env. stringency	1.609** (0.746)	1.464 (1.668)	0.638 (0.854)	−1.036 (1.451)	1.850 (0.983)	1.316 (1.366)
GDP squared * env. stringency	−0.080** (0.036)	−0.080 (0.082)	−0.034 (0.041)	0.044 (0.071	−0.091 (0.047)	−0.068 (0.069)
EFW indicator	0.547 (1.164)	1.426 (3.055)	−1.678 (1.664)	−5.547 (4.858)	−1.008 (2.283)	−1.734 (2.893)
GDP * EFW indicator	−0.198 (0.239)	−0.336 (0.632)	0.389 (0.364)	1.279 (1.111)	0.168 (0.468)	0.289 (0.603)
GDP squared * EFW indicator	0.014 (0.012)	0.019 (0.033)	−0.022 (0.019)	−0.073 (0.063)	−0.007 (0.024)	−0.011 (0.031)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	231	189	231	189	231	189
Countries	42	42	42	42	42	42
Within R squared	0.589	0.096	0.540	0.137	0.550	0.094
F statistic	28.72	3.96	29.34	3.18	40.64	4.51

Note: *** (**) [*] denote significance at $p < 0.01$ ($p < 0.05$) [$p < 0.10$]. Numbers in parentheses are standard errors clustered at the country level, only democracies are included and the ten largest oil and gas producers are excluded.

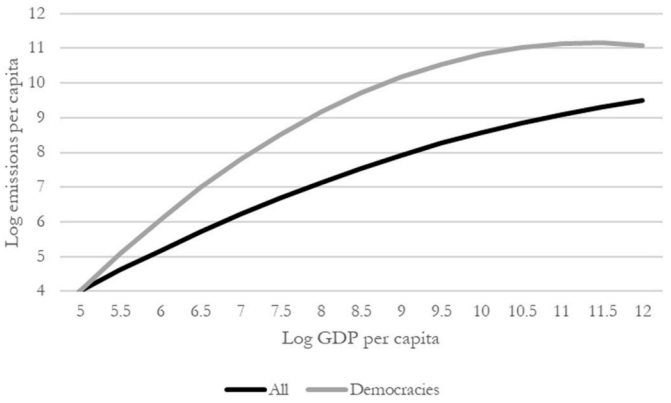

Fig. A1. Implied Kuznets Curves, no interactions.

CRediT authorship contribution statement

Christian Bjørnskov: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

I hereby declare that I have no conflicts of interest.

Data availability

Data will be made available on request.

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