An Empirical Investigation into Carbon Lock-In: What Determines the Stringency of Environmental Policy?

Julian Marenz
Maastricht University
j.marenz@student.maastrichtuniversity.nl

ABSTRACT
Carbon lock-in is referring to the prolonged utilization of a fossil-based energy system despite an increasing number of reasons for the shift to alternative technologies. This paper uses environmental policy stringency (EPS), an index published by the OECD, as a proxy for carbon lock-in. A fixed effect and a generalized methods of moments estimator are used. These approaches yield the conclusion that EU- membership and GDP per capita are associated with a higher EPS. Furthermore, electricity production from coal, gas and oil sources has a small positive, and GDP growth a small negative impact on EPS.

Keywords
Carbon Lock-In, Environmental Policy, Climate Change

INTRODUCTION

The Paris Agreement which was signed in 2016 postulates that the increase in the global average temperature is to be kept below 2 °C as compared to pre-industrial levels. Additionally, the participating countries stated that they are willing to make a serious effort to keep it below 1.5 °C. The Intergovernmental Panel on Climate Change (IPCC) released a special report in 2018 which concluded that "unprecedented" cuts in greenhouse gas (GHG) emissions will be necessary if the self-proclaimed target is to be achieved (Bongaarts, 2019). Reaching such reduction objectives will hinge on the successful implementation of environmental policy that is restructuring the current system to substantially decrease pollution. However, conduct of said policy will be constrained by a number of factors that are economic, institutional and technological in nature. Inertia associated with these different forces can lead to a slow adoption of progressive action that is so desperately needed in the face of climate change.

The problem of moving away from an equilibrium that was reached through a path dependent process has been discussed in the economic literature and the term lock-in emerged to describe it. This concept was applied to the continued usage of carbon technologies, which are responsible for 76 percent of the global GHG emissions according to data of the US Environmental Protection Agency (2017). Carbon lock-in is constituting a significant barrier to the attainment of pollution reduction objectives which could be achieved through the increased reliance on renewable resources (Unruh, 2000). How can we empirically evaluate the degree of carbon lock-in and investigate what is driving it? Finding an answer to that question is important not only in the analysis of the issue, but also in the process of finding a solution.

PREVIOUS RESEARCH

The notion of carbon lock-in is referring to barriers concerning the shift to renewable energy of political, institutional and technological nature. These barriers have been described by the term Techno-Institutional-Complex (TIC) (Unruh, 2000). It is a conceptual framework which postulates that a technological system and both public and private institutions are interdependent. Technological and institutional increasing returns to scale drove the path dependent process that led to lock-in into carbon technologies. A feedback cycle associated with the technology on the firm, industry, societal and governmental level solidifies the status quo.

One example of a technology that is difficult to move away from is coal-fired power (Erickson, Kartha, Lazarus & Tempest, 2015). While it is costly to build a coal plant, operating it is relatively inexpensive. Political forces are actively supporting the maintenance of the status quo through the likes of e.g. subsidies (see Coady, Parry, Sears & Shang, 2017). Moreover, social forces have been advocating the continued usage of coal, or at least a slow phasing out process, stressing the importance of jobs in that sector. Investing in such an asset, or, more generally, in any asset that is prone to lock-in, flexibility in the future is severely restricted. One study used the level of investment into physical capital until 2030 to evaluate the effect it has on the extent of carbon lock-in (Bertram et al., 2015). Different emission scenarios were employed, where electricity generation and the consumption of combustible fuels were identified as the most problematic technologies with regard to reaching reduction objectives. It was concluded that weak near-term climate policies incentivize further utilization of carbon technology.

A price on carbon might be insufficient to achieve a regime shift. Instead, a mix of public and private investment into green capital will be crucial in achieving a shift to renewable resources (Kemp-Benedict, 2014). However, this shift will be accompanied by a number of macroeconomic disruptions, such as a change in employment structures, inflation rates and debt levels. In light of these disruptions government will have to provide long-term certainty with respect to their policy choices, in order to stimulate the necessary investment. Directly opposing this, it has also been argued that stability does not need to be one of the main goals of individual climate policies (Rosenbloom, Meadowcroft & Cashore, 2019). Due to the complexity of the phenomenon itself, the multitude of implications for different actors within a society and around the globe, and an associated general uncertainty, the overall direction of policy, that is, transition towards a low emission economy, should be clear, while granting flexibility with regard to individual policies.

MOTIVATION

Stringency with regard to policy efforts in decarbonizing the economy has been cited as being indispensable to escape carbon lock-in. However, the TIC is likely to constitute a major obstacle to this very goal. Through which channels do institutional, technological and economic forces affect policy? The influence of different factors pertaining to the political economy of carbon pricing have been illustrated using panel data on a variety of countries (Dolphin, Pollitt & Newbery, 2016).

The authors constructed an index that is relating the price that is put on carbon within an economy (through both taxes and cap-and-trade systems) to the quantity of Greenhouse Gas (GHG) emissions, out of the total, covered by that price. It does not include non-market instruments such as command-and-control regulations or government R&D expenditures. However, discontinuity and research subsidies have been identified as important factors that could contribute to the escape of carbon lock-in. For the OECD countries, the Environmental Policy Stringency Index (EPS), a measure including these dimensions, is available (see Botta & Koźluk, 2014). Due to the broader scope, the latter is likely to constitute a better proxy for overall decarbonization efforts than the former.

In my empirical analysis, I will use EPS, which serves as an indicator of lock-in into an economy based on carbon technologies, as the dependent variable. This internationally comparable index is ranging from 0 (not stringent) to 6 (highest degree of stringency). Stringency is measured by the degree to which environmental policy instruments, mainly related to air pollution and climate, put an explicit or implicit price on environmentally harming behavior or polluting. It is also including command-and-control regulations and government R&D expenditures. EPS constitutes a good proxy for carbon lock-in because it captures notable features. A stringent policy is indicating that barriers of institutional and political nature that impact legislation have been overcome. Moreover, innovation could be incentivized, which might help to overcome technological lock-in; and it can serve to change the structure of private institutions. The inertia to implement policy, another determining characteristic of carbon lock-in, appears to be less of an issue if observed EPS is high. Thus, a more stringent environmental policy suggests a lower degree of lock-in, at the very least on a political level. The contribution of this research to the academic literature is an evaluation of the theory on carbon lock-in in the context of an empirical model.

DATA

In the previous section, I have elaborated on the EPS being an appropriate proxy for carbon lock-in. The question that arises is as to what the determinants of policy stringency are. While the reinforcement of inertia between institutions and the technological system, jointly constituting the TIC, has been cited to be a reason for carbon lock-in, it is self-evident that the macroeconomic environment also has a decisive influence on policy. Consequently, I hypothesize the degree of carbon lock-in to be determined by a number of factors that can be classified as belonging to the aforementioned categories. I will include the following explanatory variables:

Electricity Production from Coal, Gas and Oil Sources **(**I am utilizing the electricity production from coal, gas and oil sources as a percentage of the total inputs in use to generate electricity); Development of Environment-Related Technologies (it is a measure that is indicating the per million capita inventions in the field of technologies that are related to the environment); Industry (I will use the value added by the industry sector as a percentage of the GDP); EU Membership (the regression is including a dummy variable that is equal to one in the case that a country is a member of the EU in a particular year); GINI (as a measure for income inequality I use the GINI index - unfortunately, data on most of the countries was only available for the time period including 2003 and after, with some single observations before that); GDP per Capita and GDP Growth (data on the GDP per capita is measured in current US Dollar). Data was taken from the OECD and the World Bank.

Due to constraints regarding data on each of these variables, I will restrict my attention to a selected number of member countries of the organization for economic co-operation and development (OECD). Moreover, the G20 countries Brazil, China, India, Indonesia, Russia and South Africa are included. The period that I am investigating is 1990 – 2012 in the full sample, however, for some parameters data was only available for a shorter time span.

EMPIRICAL SPECIFICATION

Due to issues relating to the stationarity of GDP it was not possible to run a regression for the whole time period including the level. This is why I have divided my empirical part into a full sample, using a fixed effects (FE) approach and a restricted sample, using the generalized methods of moments (GMM) estimator.

The Full Sample

When attempting to draw causal inferences from statistical analysis, omitted variable bias can oftentimes constitute a problem because the inclusion of every factor that has an influence on the dependent variable is a burdensome task. This complication, at least in part, derives from the fact that there are variables on which data is difficult to obtain. One solution is the fixed effects (FE) approach, which does allow to control for unobserved heterogeneity that is constant over time but varies across entities (Stock & Watson, 2015). Conducting a Wooldridge test for autocorrelation in panel data, I conclude that it is necessary to include a lag of my dependent variable. While I acknowledge that the Nickell bias might constitute a problem in a small T large N context, Pesaran (2015) indicated that this is more of a problem if $T < 9$. For the full sample I will use the following specification:

$$EPS_{i,t} = \alpha + \beta\, EPS_{i,t-1} + \psi' X_{i,t} + \gamma' Z_{i,t} + \phi_i + \lambda_t + \epsilon_{i,t}$$

Where $EPS_{i,t}$ is the environmental policy stringency index, α is the common intercept, X_{it} is a vector including variables relating to the TIC, Z_{it} is a vector including variables relating to the economic environment, ϕ_i are country-specific fixed effects and λ_t are time fixed effects. The latter is included because a time dummy could be correlated with the explanatory variables. Failure to account for that would create omitted variable bias. Said time effect is common to all entities but does differ for each year. While β is the coefficient of the lagged dependent variable, ψ' and γ' are vectors of the coefficients pertaining to the TIC and the economic environment respectively. Heteroskedasticity could lead to a false conclusion regarding the validity of my estimates, which is why I have used robust standard errors that are clustered at country level (see Wooldridge, 2010).

The Restricted Sample

A unit root test on my subsample (2008 – 2012) indicates that all of my data is stationary in levels. This time frame was chosen because it is including the most recent data, which could be important in the dynamic field of environmental policy. However, a concern that arises is the considerable bias of the fixed effects estimator if T is small due to correlation of the lagged dependent variable and the error term (Pesaran, 2015). A possible remedy for this problem is the generalized methods of moments (GMM) estimator which is exploiting "internal instruments". Their usage is not restricted to the dependent variable but can also be utilized for possibly endogenous explanatory variables as they themselves are correlated with the error term. Hence, while I have assumed my regressors to be strictly exogenous in the previous estimates, this approach is also well suited to address endogeneity concerns (Roodman, 2009).

RESULTS

The results from the FE and the GMM estimates are mixed. This is not only due to the different nature of the approaches but also due to the different time periods investigated. Nevertheless, it is possible to derive some general conclusions from my estimates. Firstly, in most of the specifications the dependence on past values of stringency is evident. One factor contributing to this is the nature of the policy-making process, which is oftentimes rather slow. An interesting thing to note is that this dependency decreased when estimating a regression that is utilizing more recent data. It is likely that the seriousness of climate change has been recognized and countries which have been displaying inertia to implement stringent policy at the beginning of my sample are increasingly willing to do so. Notwithstanding, the implementation of a relevant legislation, such as the EU Emission Trading System (ETS), does lead to a one time jump in EPS. Such observations, where EPS_t is substantially different from EPS_{t-1}, will carry more weight if the time span investigated is shorter and lead to a lower magnitude of the coefficient on the lagged dependent variable.

Secondly, countries that have been relying more extensively on fossil fuels in the electricity production did seem to be more stringent in their environmental policy over the complete time horizon. This might be a reason for slight optimism, considering that the problem of a carbon intensive energy sector has been realized by policy makers and that this sector does not constrain action as evaluated by environmental policy. However, considering that the cross-sectional mean of the share of carbon used in electricity producing stayed relatively constant between 1990 and 2012, decreasing from 57.57 percent to 54.02 percent, whereas the mean of stringency in environmental policy did increase substantially from 0.75 to 2.70, there is some evidence that this increased stringency is failing to reduce the usage of fossil fuels, at least in electricity production. Taking into account the lifetime of a coal power station (between 40 and 50 years) or a gas power station (around 30 years) this should not be surprising, and one might expect the effect of policy to materialize with a substantial delay.

Thirdly, EU membership has a positive impact on the pursuit of EPS objectives. This does indicate that some measures introduced by the EU could serve as a role model for other governments, political unions or economic unions, that are willing to tackle climate change through strict environmental policy. It is not unlikely that some countries which are part of the union are more ambitious in their decarbonization effort mainly because their membership requires them to.

Lastly, while GDP growth has a negative effect on stringency, the level of the GDP has a positive impact. It does seem plausible that economies that are growing faster are less willing to constrain this growth in the short-run through the implementation of strict environmental policy. Furthermore, the positive effect of the level can be understood as demonstrating the ease with which stringency can be exercised in the case that a country is wealthy enough to afford such an approach. Combining these two insights yields an alarming conclusion. In 2018, the fastest growing economies were on the lower end of the global income distribution (International Monetary Fund, 2019). Hence, both the level and the growth effect would indicate a low level of stringency. In the case that these countries will embark on a similar trajectory as the countries within my sample with regard to the development of their economy and the implementation of policy, it is hard to believe that climate change can be tackled effectively on a global scale. While a high level of growth would ultimately culminate in a high level of GDP, the latter being associated with increased stringency, the urgency of the issue might not leave a lot of room to wait for this effect to occur. This is the reason why cooperation between mature economies, which are responsible for a significant amount of the pollution during the last decades, and low-income countries, which are aspiring to reach the same level of prosperity, is indispensable.

LIMITATIONS AND FUTURE RESEARCH

Evidently, there are limitations to this research. The data I have utilized is not complete and there are some missing observations. If there is a pattern for certain variables where data is not available, this has the potential of introducing a bias to my results. Furthermore, as discussed previously, the strict exogeneity assumption pertaining to the electricity production from carbon sources in the FE estimates might pose an issue. It could also be the case that other variables, such as the industry share, are endogenous to my model due to the fact that the level of stringency in environmental policy will impact them. Omitted variable bias could also constitute a problem. While the FE and the GMM estimates allow to control for unobserved factors that are constant over time, it is not accounting for variables that might change over time and that I have failed to include in my model. Future research could investigate a set of developing or low-income countries and see whether and to which extent they differ from the sample used in this study. Furthermore, it could include variables that have not been considered in this research.

CONCLUSION

This research is the first one to use the stringency of environmental policy to empirically evaluate carbon lock-in and the factors that determine it. Through a FE approach, it has illustrated the drivers behind the implementation of a stringent policy between 1990 and 2012 in countries that belong to the OECD or the G20. In addition to that, the GMM estimator was used to conduct an analysis of a shorter and more recent time span. The implications of the results are that countries which have been more reliant on fossil inputs in their electricity production are appearing to be more stringent in their policy. Moreover, membership in the EU increased the value of EPS. Ultimately, while richer countries appear to experience a lower degree of carbon lock-in, GDP growth is constituting an obstacle to a decarbonization of the economy. With regard to the sample that has been investigated this would call for either a successful decoupling of economic growth and the pursuit of pollution objectives, if somehow possible, or, in the light of climate change, for a questioning of the omnipresent growth rational as such. While growth will lead to an increased stringency in the future due to a higher level of GDP, a debate about urgency is necessary. Furthermore, it is much needed that low-income countries are taking a different path in their development than the OECD and G20 countries, as for otherwise pollution will vastly increase. Due to the prosperity of the latter set of economies, which are also responsible for most of the GHG emissions in the past, global cooperation and assistance, if necessary, in the implementation of a stringent environmental policy is indispensable.

ROLE OF THE STUDENT

Julian Marenz was an undergraduate student working under the supervision of Robin Cowan when the research in this report was performed. The student came up with the topic and consequently carried out the empirical part himself. Throughout the process the supervisor gave a lot of helpful comments and suggestions.

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