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Rescuing Comparative Law and Economics?
Exploring Successes and Failures of an Interdisciplinary Experiment

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CLEAN INNOVATION TO CLIMATE RESCUE: A COMPARATIVE LAW & ECONOMICS ANALYSIS OF GREEN PATENTS REGULATION

Noemi Mauro[*]

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Using a Comparative Law & Economics methodology (CLE), this article intends to contribute to the debate on the relationship between institutions, green patent filing and the rate of innovation in the environmental field. An introductory section addresses the necessity of analyzing the interrelation between patent rules around the world and green innovation. The discussion then explores which institutions concerning clean patents are responsible for improving the rate of inventions for low-carbon technologies. Attention is given to countries ranking high as fundamental market recipients of new patented technologies, namely China, the U.S., Japan, South Korea, and Germany. This comparison will develop in a two-step analysis: (1) A discussion on the impact that different types of institutions have in incentivizing or hindering patent applications, and (2) whether this results in increased rates of clean innovation, with consistent effects in fighting climate change. The main methodological issues are: (a) Considering the array of different drivers of innovation, in a complex, multifactorial environment; (b) determining what kind of legal transplants could be carried on by States lacking relevant involvement in green innovation, modelling on those more proactive in the field. Rather than identifying a generic set of guidelines that could be replicated around the world in terms of efficient institutions for low-carbon technology innovation. The goal should be to use CLE to assist policymakers in recognizing which country-specific and local factors are most relevant for green innovation.

I. INTRODUCTION: THE ADDED VALUE OF A COMPARATIVE LAW & ECONOMICS APPROACH TO ECO INNOVATION

Green Intellectual Property Rights (IPRs) aim to legally protect clean technology inventions[1]. Developing innovations beneficial to the environment is one of the core strategies to address climate change[2]. Technology is the primary cause of pollution, as industrialization is the main factor contributing to the increase in extreme climate events. Nevertheless, it can also be the

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[1] Definition of 'clean technology' as interchangeable with 'environmentally sound technology', see WIPO Green (Pilot) Charter and IPC Green Inventory, both at www.wipo.org . On this point and for the relationship genus-species of the terms 'green technology' and 'clean energy technology': J.M.W.W. Chu, *Developing and Diffusing Green Technologies: The Impact of Intellectual Property Rights and their Justification*, in 4 Wash. & Lee J. Energy, Climate & Env't. 53 (2013).

[2] On the role of patents to address the issue of climate change, see, e.g., IRENA, *The Role of Patents in Renewable Energy Technology Innovation*, June 2013; A. Aberdeen, *Patents to Climate Rescue: How Intellectual Property Rights are Fundamental to the Development of Renewable Energy*, 4iP Council, October 2020; IEA, *Patents and the Energy Transition* (Paris: IEA, 2021).

most relevant solution to tackle the problem[3]. The global drive to accelerate innovation must be significant and coordinated across countries to reach net-zero emissions, using cutting-edge technology to reduce reliance on limited natural capital resources. With the rise of mitigation and adaptation techniques in this field, there is a pressing need to create a robust innovation framework and make effective national and international IPRs systems more accessible to maintain the increasing growth of technology, goods, and services needed to build a greener future. IPRs can and must fulfil a pivotal role in stimulating environmental-friendly inventions. The literature on this topic accounts for both optimistic and more skeptical approaches, offering fertile ground for debating between those advocating in favour of the role IPRs play in R&D and commercialization of green inventions and those lamenting the barrier these rights create towards developing countries, granting artificial monopoly revenues that prevent the international transfer of knowledge[4]. To what extent, then, IPRs (with a specific focus on patents) influence the diffusion of green technologies? It seems to be an almost impossible question to answer through empirical analysis, due to the complex nature of these rights. Their effect on promoting or slowing down the pace of clean innovation is still unclear[5]. However, it is undoubted that IPRs have an impact on the development of (clean) technologies[6]. Moser even goes as far as to conclude that 'patent laws influence the direction of innovation'[7].

The scope of the present paper is to analyse the nature of this influence and the repercussions on the global fight against climate change, under the lenses of Comparative Law & Economics (CLE). The choice of adopting the CLE methodology comes along as almost natural for such a study, given the transnational nature of the climate phenomenon and the complexities it involves. For what concerns the global diffusion of environmentally sound technologies, the challenge regards the so-called 'double externality'. This dual-sided problem exists because (a) pollution is a negative externality, influencing others than those deciding in the context of a market economy and (b) the nature of the knowledge to develop (green) technologies is non-rival and non-excludable[8]. The non-appropriability of knowledge

[3] Chu, *supra* note 1, at 71.
[4] Chu, *supra* note 1, at 55.
[5] On this point see e.g. C.M. Kalanje, *Role of Intellectual Property in Innovation and New Product Development*, available at www.wipo.org; Chu, *supra* note 1, at 73.
[6] As an example, in this sense: P. Moser, *How Do Patent Laws Influence Innovation? Evidence from 19th-Century World Fairs*, in 95(4) Am. Econ. Rev. 1214-36 (2005).
[7] *Ibid.*, at 28.
[8] B. H. Hall, C. Helmers, *The Role of Patent Protection in (Clean/Green) Technology Transfer*, in 26 Santa Clara Comp. & High Tech. L.J. 487 (2010).

produces a divergence between private and social returns to R&D in the production of inventions. Due to these two aspects that interact and compound, returns on innovation see a decrease that disincentivizes the efforts and resources put into developing new clean technologies[9].

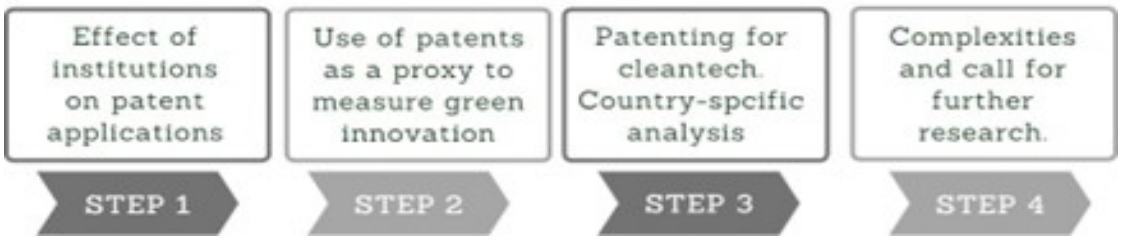
IPRs are often seen as a possible solution to the imperfect appropriability of knowledge. They produce two types of economic effects: static and dynamic[10]. On the one hand, the static impact is related to the fact that such rights create social welfare loss deriving from artificially inflated prices. On the other hand, IPRs allow for the right prompt to invent due to the possibility for innovators to charge monopoly prices[11]. In particular, a robust patent system is capable of promoting the development of all types of technologies, including those related to cleantech[12]. It becomes interesting at this point to further inquire about the choices made by some states in terms of eco-innovation, namely: China, the U.S., Germany, Japan, and South Korea. They have been selected because they account for a rapid and significant increase in patenting activity in green energy technologies during the last decades[13]. According to the OECD's Technology Diffusion Indicator, these jurisdictions are sought by inventors to give protection to their environmentally-sound inventions, becoming fundamental markets for the commercialization of new technologies (which does not imply they rank high in terms of the consequent development)[14]. The CLE methodology perfectly suits the task, providing the right tool to further understand the motivations for the existence of certain legal rules and institutions and their evolution through time[15]. Not only the study of domestic legislation, but also the interactions among different legal systems are of interest to the appreciation of divergencies and convergencies in approaches to green patent activities. Why are certain states performing better than others in terms of innovation? Can it be related to different institutional frameworks supporting environmental growth? Finding virtuous practices among these five states would entail addressing the possibility of subsequent legal transplants of these efficient rules to less innovation-performing countries. The hypothesis of a consequent transplant needs to take into account the mechanism of

[9] *Ibid.,* and OECD, *Raising the Returns to Innovation: Structural Policies for a Knowledge-based Economy*, in OECD Economics Department Policy Notes, 17 (2013).
[10] For a more extensive discussion about the types of economic benefits of intellectual property rights, see: W. M. Landes, R. A. Posner, *The Economic Structure of Intellectual Property Law* (Harvard, MA: Belknap Press, 2003), at 4.
[11] Hall, Helmers, *supra* note 8, at 5.
[12] P. Gattari, *The Role of Patent Law in Incentivizing Green Technology*, in 11 Nw. J. Tech. & Intell. Prop. 41 (2013), at 42.
[13] K. Fushimi *et al.*, *Measuring Innovation in Energy Technologies: Green Patents as Captured by WIPO's IPC Green Inventory*, Economic Research Working Paper 44 (2018).
[14] See OECD, *Green Patents* (2015), available at: www.oecd.org.
[15] U. Mattei *et al.*, *Comparative Law and Economics*, in B. Bouckaert, G. de Geest (eds.), *Elgar Encyclopedia of Comparative Law* (Cheltenham: Elgar Publishing, 2000), at 55.

transferring technological knowledge from developed to developing countries, focusing on the elements that promote or hinder such transfer of know-how. The argument here is not that there is a one-size-fits-all solution for green innovation. Rather, a CLE approach fosters awareness of the local institutional factors which could affect it.

This paper will discuss (although not solve) the above issues in a logical order, starting from a general introduction to the relationship between institutions, patents, and the rate of green technology innovation. Consequently, an analysis of the Chinese, American, German, Japanese and South Korean legal systems in terms of patent rules and underlying institutions will be conducted. Through a diagnostic input, the attempt is to shed light on a reasoned choice of which drivers of innovation to include in further econometric studies. In short, this research paper contributes to a theoretical understanding of the complexity of studying the institutional enabling factors for green innovation. CLE, through a diagnostic analysis, can help understand such an issue by dissecting it in its components, explaining their relevance and importance[16]. Automatically, this approach will lead to asking more questions about the interdependency and causality of the factors revolving around eco-innovation[17]. The added value of this contribution is to link domains and academic articles that generally coexist but have not been integrated, to understand why some countries are more likely to perform better than others in terms of environmental innovation.

Figure 1. Main steps of the analysis on institutional drivers of eco-innovations.



II. FIRST STEP OF THE ANALYSIS: EFFECT OF INSTITUTIONS ON PATENT APPLICATIONS (AS A MEASURE OF INNOVATION)

The causal link between the degree of green innovation of a certain country and patent rules as designed in that same country is still of unclear nature. Most of the literature in the field

[16] G. Bellantuono, *Comparative Legal Diagnostics,* Working Paper 7 February 2012, at 14, available at www.ssrn.com.
[17] *Ibid.*

concentrates directly on the relationship between institutions and innovation, mainly using patents as a proxy for the rate of inventions in a country. Before assessing the choice of using patents to measure innovation (Section III), more needs to be said in terms of the association between institutions and innovation. Several empirical studies try to evaluate whether there is causation, correlation, or no connection at all between these variables, using econometric tools. In one of the most recent pieces of research on the theme, Donges *et al.* look at how inclusive institutions affect innovation, using newly assembled data sets for Imperial Germany[18]. The historical perspective is in line with the CLE approach, concentrating mainly on a dynamic analysis that attempts to account for the interplay of judicial systems across time, with a particular emphasis on legal evolution. Donges *et al.* study the development of patents' role in early Germany, analyzing the differences across German states and the influence that the French institutions (in particular, the *Code civil*) had on German patent law[19]. The authors clearly state that variations in patent rules influence innovation[20]. They conclude that there is a «*quantitatively large effect of institutional quality on patenting activity*», providing evidence that counties that were occupied by the French were able to develop better institutions in a shorter time compared to those left free. This factor resulted in a doubled number of patents per capita in the year 1900[21].

In another study, Tebaldi and Elmslie chose to use cross-country data and the instrumental variable method to assess whether institutions influence inventions, using patent production across countries as the proxy for the dependent variable 'rate of innovation'[22]. The authors' research reveals that institutions have a growth effect on income because institutional quality influences an economy's rate of innovation, which is 'the engine of economic growth'[23]. Therefore, their findings specifically address the effect of innovation on society, which is to stimulate the general social welfare. Technical innovation (expressed in terms of patent production) is seen as a mechanism to generate growth, and the econometric model adopted confirms the role institutions have in this causal cycle. Tebaldi and Elmslie selected four different types of institutions to test their influence on patent production, discovering that *«control of corruption, market-friendly policies, protection of property rights and a more effective judiciary system boost an economy's rate of innovation»*[24].

[18] A. Donges *et al.*, *The Impact of Institutions on Innovation*, in Mgmt. Sci. Articles in Advance, 28 April 2022.
[19] The authors' choice to include the French influence on Germany is because, for geostrategic considerations, France occupied areas of Germany after the French Revolution. Longer-occupied regions were early adopters of more inclusive institutions, whose impact on innovation has been the center of this study. *Ibid.*, at 7f..
[20] *Ibid.*, at 17f., recalling Moser (2005), *supra* note 6.
[21] *Ibid.*, at 8f..
[22] E. Tebaldi, B. Elmslie, *Do Institutions Impact Innovation?*, MPRA Working Paper 8757 (2008).
[23] *Ibid.*, at 3.
[24] *Ibid.*, at 2.

van Waarden contributes to the present discussion, focusing on the impact that formal institutions, especially laws, have on the rate of innovation of a certain country. He talks about 'national systems of innovation'[25], meaning that the overall framework of institutions that a country has set in place significantly influences its innovative outcome. The author affirms that variation in institutional factors can explain the differences in the inventive performance of nations[26]. In exploring the relationship between legal rules and innovations, van Waarden does not fail to account for the complexity of such a task, pointing out the 'dilemmas and paradoxes' met along with the study[27].

In general, many scholars seem to agree on the fact that institutions do matter for innovation and growth. From the early studies[28] till nowadays, the academic world has been researching and positively answering such questions. However, do institutions impact not only innovation in general but also, specifically, green inventions? Bosetti *et al.* recall the importance of developing new technologies to tackle climate change, supporting their view with simulation exercises that assess how certain policies can effectively produce induced green innovation. Some of these policy tools are carbon taxes, research and development programs, and subsidies for the adoption of available technology[29]. Along this line, Veugelers restates the pivotal role that incentives to private actors can play to transition to cleaner technologies[30]. Moreover, by looking at institutional theory and innovation literature, it is noticeable how increased governmental and normative pressures on environmental challenges positively affect enterprises' tendency to engage in clean technological innovation. Berrone *et al.* argue how eco-innovation is influenced by regulatory and legislative pressure, especially on less environmentally performing firms that seek clean technological improvements to rehabilitate their image in the eyes of the world[31].

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[25] F. van Waarden**,** *A Prototypical Institution: Law, Regulation and Innovation,* in S. Casper, F. van Waarden (eds.) *Innovation and Institutions* (Cheltenham: Elgar Publishing, 2005), 229.
[26] *Ibid.*
[27] *Ibid.,* at 230.
[28] D. Acemoglu *et al.*, *Institutions as the Fundamental Cause of Long-Run Growth*, in P. Aghion, S. Durlauf (eds.), *Handbook of Economic Growth* vol. 1A (Amsterdam: North-Holland, 2005), 386-472; D. Acemoglu, J. Simon, *Unbundling Institutions*, in 113(5) J. Pol. Econ. 949-95 (2005).
[29] V. Bosetti *et al.*, *The Role of R&D and Technology Diffusion in Climate Change Mitigation: New Perspectives Using the WITCH Model*, in OECD Economics Department Working Papers 664, OECD Publishing (2009), at 5.
[30] R. Veugelers, *Which Policy Instruments to Induce Clean Innovating?*, in 41(10) Res. Pol'y 1770-1778, at 1770 (2012).
[31] P. Berrone *et al.*, *Necessity as the Mother of "Green Inventions": Institutional Pressures and Environmental Innovations,* in 34 Strat. Mgmt. J. 891-909 (2012).

It appears that institutions, in the broader sense of the term, including formal and informal ones, do have a say in eco-innovation[32]. As recalled by Hojnik and Ruzzier, 'research in this area primarily adopts the resource-based and institutional theories as its theoretical foundations'[33], which would not be the case if institutions were not relevant. Therefore, it can legitimately be asked what the factors driving green inventions are in general. The authors report how regulation seems indeed to be the most frequent and mainstream element influencing the rate of cleantech innovation, followed by market pull factors[34].

The next step of this analysis will revolve around the second link highlighted in Figure 1, i.e., the correlation between the number of patents and rates of eco-innovation.

III. SECOND STEP: DO MORE CLEAN PATENTS PRODUCE HIGHER RATES OF GREEN INNOVATION?

Surely, the data on the number of patents for clean technologies have been widely adopted as a proxy to *«measure the results of innovation policies»*, e.g., by the OECD, which used patent data for measuring and analyzing innovation in its 2015 report concerning the *«analyses of narrow technological fields such as many environment- and climate-related technologies»*[35]. However, almost every study about eco-innovation, and using patents as means of evaluating it, carefully contextualizes the choice. The most adopted disclaimer regards the fact that, despite being useful indicators in many ways, patents bring along limitations that are worth being mentioned. On the one hand, patents are often used as markers to measure innovation because, when compared to other options, they have several appealing features[36]. Some of these properties, as mentioned by Haščič and Migotto, are their wide availability, quantitative, commensurability, output-orientation, and capability of being disaggregated[37]. Moreover, patents provide a great deal of information on the invention per se, the inventor(s) and, in general, several details on the application. On the other hand, not all inventions are patented;

32 'There is a consensus in this literature regarding regulation, technology push, and market pull as drivers of eco-innovation' (P. Demirel, E. Kesidou, *Sustainability-Oriented Capabilities for Eco-Innovation: Meeting the Regulatory, Technology, and Market Demands*, in 28(5) Bus. Strat. and the Env. 847-857 (2019)). Also see N. Arranz *et al.*, *Innovation as a Driver of Eco-Innovation in the Firm: An Approach from the Dynamic Capabilities Theory,* in 29(3) Bus. Strat. and the Env. 494-1503 (2020), who argue that innovation, in general, can be considered a driver (and thus a premises) for eco-innovation.

33 J. Hojnik, M. Ruzzier, *What Drives Eco-Innovation? A Review of an Emerging Literature,* in 19 Env. Innov. and Soc. Trans. 31-41 (2016).

34 *Ibid.*, at 39.

35 I. Haščič *et al.*, *The Use of Patent Statistics for International Comparisons and Analysis of Narrow Technological Fields*, OECD Science, Technology and Industry Working Papers 2015/05.

36 I. Haščič, M. Migotto, *Measuring Environmental Innovation Using Patent Data*, OECD Environment Working Papers no. 89 (2015), at 7.

37 *Ibid.*, at 16, for an in-depth analysis of these prominent features as well as the disadvantages.

although it is also true that there are few cases of economically relevant inventions that have not gone through the pathway of patent application[38]. In addition to that, not all inventions meet the requirements to be patented (novelty, non-obviousness, and usefulness), which sometimes makes the inventors opt for other forms of IPRs, namely trade secrets.

For the purposes of this paper, it is relevant to mention that Haščič and Migotto note how 'patent data are best suited for identifying specifically 'environmental innovation', because of their inner 'technical' nature. Unlike other kinds of classifications (commodity and industrial), patents allow for a detailed description of key technologies by specifying the engineering elements of an invention, which suits the highly technological nature of clean inventions[39]. After mentioning the difficulties in choosing the right proxy to measure innovation, Tebaldi *et al.* opt to refer to the number of patents registered in a given period as a quantification tool for inventiveness. Their choice is justified by mentioning a wide array of literature in support of using patents, although several drawbacks are put forward, similar to those mentioned above[40]. Lastly, two more elements need to be considered. Urbaniec *et al.* evoke that the number of patents does not necessarily imply their respective relevance or influence in the practical field[41]. Griliches turned his attention to the object of patent- related measurement: Do patents quantify the input or output of innovation? Additional variables would require to be included, for example 'input measures such as R&D expenditures, and output measures such as productivity growth, profitability, or the stock market value of the firm'[42].

A radical vision against patents is offered by Boldrin and Levine, who underlined how patent systems are exposed to risks of lobbying and rent-seeking. They suggest completely abolishing patents, in favor of other, more efficient, legislative tools and policies[43]. For completeness, as a more nuanced position, Wagner explicitly analyzed whether and how patent data can be used to identify eco-innovations and if such data can be used for

[38] *Ibid.*, at 15. For the answer to the criticism on patents, see H. Dernis, D. Guellec, *Using Patent Counts for Cross-Country Comparisons of Technology Output*, 27 STI Rev. 129 (2001).
[39] Haščič, Migotto, *supra* note 36, at 17.
[40] For the literature in support of using patent data as a proxy to measure innovation see Tebaldi, Elmslie, *supra* note 22, at 7.
[41] M. Urbaniec *et al.*, *Measurements and Trends in Technological Eco-Innovation: Evidence from Environment-Related Patents*, in 10(7) Resources 68 (2021).
[42] Z. Griliches, *R&D and Productivity: The Econometric Evidence* (Chicago, IL: University of Chicago Press, 1998), at 297.
[43] M. Boldrin, D. K. Levine, *The Case Against Patents,* in 27 (1) J. Econ. Persp. 3-22 (2013).

quantitative econometric analysis[44]. He concludes that the use of patent data to measure environmental-related innovation is 'a more conservative approach that identifies only the more radical environmental innovations'. The reasons he gives are multiple: (a) It might be that the invention is protected with other means such as trade secrecy, (b) the invention could have been made under public funding, thus with the condition of public disclosure or even (c) it could be that the firm has no interest in preventing others from freely using the inventions[45]. Therefore, the link between patent filings and innovation outputs is still debatable[46].

IV. PATENTING FOR CLEANTECH

So far, the discussion has allowed us to explore the influence of institutions on patents, as a proxy for innovation, and the relationship between green patents and eco-innovation. The general outline of the Chinese, American, German, Japanese and Korean jurisdictions is meant to offer an overview of the role that institutions have in promoting patenting activities and thus produce a higher rate of innovation. The CLE methodology, supporting the review of the literature on the theme, induces a focus on legal and economic aspects of these countries, such as the way institutions are used to address and reduce risks and uncertainties related to innovation systems. It will be possible to notice how the outcome is not always positive for all jurisdictions, as the American case suggests[47].

Origin	Patents	Marks	Designs
China	1	1	1
U.S.	2	2	4
Germany	5	4	3
Japan	3	5	8
Republic of Korea	4	11	2

Figure 2. Ranking of total (resident and abroad) IP filing activity by origin, 2020.[48]

[44] M. Wagner, *On the Relationship Between Environmental Management, Environmental Innovation and Patenting: Evidence from German Manufacturing Firms*, in 36(10) Res. Pol'y 1587-1602, 1589 (2007).
[45] *Ibid.*, at 1590.
[46] A quite complete study in this sense is R. Kempt, P. Pearson, *Final Report MEI Project about Measuring Eco-Innovation* (European Commission, 2007), 15-22.
[47] See F. van Waarden, S. Casper, *Conclusion: Questions for Further Research*, in Casper, van Waarden, *supra* note 25, 265.
[48] WIPO, *World Intellectual Property Indicators 2021*, at 8, available at www.wipo.int.

IV.1 THE CHINESE CASE

The National Intellectual Property Administration of the People's Republic of China (CNIPA), the Chinese Patent Office, recorded a 6.9% growth in patent filings in 2020[49]. The number is more than twice the amount registered at the United States Patent and Trademark Office (USPTO) in the same year. China undoubtedly classifies first in the ranking for total resident and abroad patenting activity. How is this high rate of innovation explainable? Are there specific Chinese institutions affecting in a significant way the number of (green) patents in the country? The majority of the studies on clean patents and institutions come from this country, signaling the great interest shown towards the issue. Zhou *et al.* focused their attention on the relationship between the Chinese Institutional Environment and Green Economic Growth in the country. They affirm that the improvement of the institutional context decreases transaction costs, promotes factor mobility to enhance resource allocations, minimizes corruption and rent-seeking, generates a fair and equitable setting for entrepreneurs, stimulates innovation, and fosters additional growth in various businesses[50]. The authors consider three main institutional sub-environments, namely the governmental, cultural, and legal ones. According to their study, a good legal environment attracts more funds, whereas the enforcement of the rule of law helps the strengthening of IPRs. As a result, entrepreneurs are more prone to innovate[51]. A country-specific institutional feature mentioned by the study is the 'Chinese style decentralization'. Due to the size of the country, decentralized local governments have more direct control over the economic growth of their community, acting as 'economic politicians'. As a consequence, governmental sub-environments also play a role in green growth, because the political and fiscal direction they embrace will determine a more or less sustainable orientation of the local economy. Lastly, cultural factors also influence eco-businesses. A positive culture for business and environmental protection avoids entrepreneurs leading their activities towards non-green innovation to make faster profits in an already mature market[52]. After conducting their empirical analysis, Zhou *et al.* suggest that an improvement of the cultural sub-environment (informal institution) will positively affect the rate of innovation in China, stating that 'we

[49] *Ibid.*, at 12.
[50] X. Zhou *et al.*, *Institutional Environment and Green Economic Growth in China,* in Complexity 6646255 (2021), at 2.
[51] *Ibid.*, at 3.
[52] *Ibid.*

should strengthen R&D on green patents to promote green transformations with environmentally friendly technological innovations'.

Han *et al.* criticize the Chinese system of fiscal decentralization adopted by local governments. The argument is that it gives incentives to inter-regional competition, 'thus forming a development model centered on short-term interests'[53]. On the contrary, Kuai *et al.* conducted a study that corroborates the thesis that fiscal (and institutional) decentralization has a positive regulatory impact on more sustainable growth and environmental protection[54]. Therefore, it can be said that the role of decentralized authorities and local fiscal policies as institutional factors affecting eco-innovation is still under assessment.

IV.2 THE AMERICAN CASE

The U.S. Patent and Trademark Office registered 597,172 applications in 2020, classifying in the second position among the countries with the highest patent filing activitu[55]. Brunnermeier and Cohen studied the determinants of eco-innovation in the U.S., using successful environmental patent applications as a proxy. Through the use of industrial organizations' literature, the authors aimed to find out the main factors influencing green innovation. Among the major findings, spending on emissions reduction is linked to a moderate but statically relevant rise in environmental eco-innovation (holding everything else equal). Although the rate of successful green patent applications is higher as abatement pressures increase (governmental institutional factor), it does not seem the case for an ex-post increase in enforcement of these abatement mechanisms[56].

van Waarden discusses the role of institutions (law in particular, which he calls 'meta-institution') to reduce risk and uncertainty in the American innovation system. He notices how activist regulation[57], typical in the U.S., can have negative effects on the rate of innovation in the country. In fact, environmental standards tend to be quite strict, rising the costs of compliance for the industry, but giving at the same time more certainty for

[53] For a complete analysis of the main hurdles hindering the growth of a green economy in China, see: J. Han *et al.*, *Technology or Institutions: Which Is the Source of Green Economic Growth in Chinese Cities?,* in 13 Sustainability 10934 (2021).

[54] P. Kuai *et al.*, *Environmental Effects of Chinese-style Fiscal Decentralization and the Sustainability Implications,* in 239 J. Cleaner Prod. 118089 (2019).

[55] WIPO, *supra* note 48, at 12.

[56] S. B. Brunnermeier, M. A. Cohen, *Determinants of Environmental Innovation in US Manufacturing Industries*, in 45(2) J. Env. Econ. and Mgmt. 278-293, 291 (2003).

[57] 'High, strict and detailed standards imposed on business and actively and fiercely implemented and enforced' (van Waarden, *supra* note 25, at 250).

implementing business strategies in the long run (as long as these standards remain constant). The trade-off between predictability and flexibility is of a difficult nature because inflexibilities result in reduced freedom to innovate. Nevertheless, the author notices how 'stricter standards provide more certainty; and can, if formulated at a high level, be a challenge for innovation, either to satisfy it, or to circumvent it'.

IV.3 THE GERMAN CASE

Regarding the impact of German institutions on the rate of green innovation in the country, Hughes and Urpelainen offer case-based evidence of some of the main institutional factors affecting German climate policies[58]. The authors chose to perform a cross-country analysis to find the main reasons explaining differences in national climate policies, which in turn partially determine the rate of green innovation. Referring to their work, it is possible to notice which aspects of the German institutional environment causally affect the development of clean technologies in the country. One of the main findings is that the German population has a strong sense of environmentalism, showing a high interest in climate change-related issues: 'In a 2006 World Value survey, 88% of all Germans considered global warming a "Very Serious" or "Somewhat Serious" threat', reports the paper[59]. Such environmentalism is canalized through the German Green Party. Therefore, public instances to mitigate climate issues receive parliamentary attention, in contrast with the situation in other observed countries, for example, the United States, where the political agenda does not have such strong public-induced attention to environmental concerns. Institutional capacity is also cited as one of the elements determining the development of German green climate policies. Institutional bodies such as the German Energy Agency, the Federal Ministry of Economics and Technology, and the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety contribute to the development of climate change mitigation strategies[60]. It seems that these factors, combined with the consistent use of regulatory instruments, positively impact the German tendency to offer strong industrial and environmental policies. As a result, the clean technology sector is dominant, public support for such measures is solid, and the energy heavy industry grows steadily.

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[58] L. Hughes, J. Urpelainen, *Interests, Institutions, and Climate Policy: Explaining the Choice of Policy Instruments for the Energy Sector,* in 54 Env. Sci. & Pol'y J. 52-63 (2015).
[59] *Ibid.*, at 58, footnote 6, with reference to the *World Values Survey Wave 5, Question 111 – Environmental Problems in the World: Global Warming.*
[60] *Ibid.*, at 58.

It is important to remember that, as mentioned by Holger *et al.*, the essential premise of the green economy innovation system is that innovative ideas are dependent not only on R&D incentives but also on the collaboration of various stakeholders and organizations involved in the green innovation process[61]. Innovation cannot be seen anymore as mere technological progress, as it was in the past. A revolution is ignited by upturns of mindsets, hence the importance covered by green movements in national political settings, such as the German *Energiewende*. According to the authors, social innovation leads and influences technical progress, preparing a fertile ground in which to plant the seed of the green revolution. What Holger *et al.* advocate for in their work is a 'co-evolution processes of technological, organizational and institutional changes', underlying the pivotal role that social and cultural institutions have in the German green innovation framework[62].

IV.4 THE JAPANESE CASE

Patents help in assessing a country's technological capabilities, as well as mapping out the networks of innovation that arise inside and within countries. Some authors have underlined the importance that Japanese universities have in creating basins of creativity to spur innovation[63]. The strong academic environment and dedication to R&D in Japan contribute to the country's leading role in technology novelties[64]. When looking at eco-innovation activities, Kemp and Pearson refer to Porter's Diamond Theory of National Advantage to demonstrate how governments can function as drivers in improving a country's competitiveness in a world economy[65]. Porter's determinants leading to comparative economic advantage include the 'Selective Factor Disadvantage'. According to the Diamond Theory, the lack of resources acts as an incentive for countries to develop competition mechanisms. Japan is one such example, especially for what concerns the energy sector. Venhammar uses evolutionary economic theory to argue that increased energy innovation in

[61] S. Holger *et al.*, *Green Economy Innovation Index (GEII) - A Normative Innovation Approach for Germany & its FEW Nexus*, in 142 Energy Procedia 2310-2316, at 2311 (2017).
[62] More on a comparative analysis of eco-innovation drivers in Germany and France can be consulted through: J. Belin *et al.*, *Determinants and Specificities of Eco-innovations – An Econometric Analysis for the French and German Industry based on the Community Innovation Survey*, in Cahiers du GREThA (2007-2019) 2011-17, Groupe de Recherche en Economie Théorique et Appliquée (GREThA).
[63] As an example, see the study of M. Yarime, *Coevolution of Environmental Regulation and Innovation Network: The Development of Lead-Free Solders in the United States, Europe, and Japan.* Paper presented at the Fourth European Meeting on Applied Evolutionary Economics, Utrecht, The Netherlands, May 19-21 (2005).
[64] Kempt, Pearson, *supra* note 46, at 20.
[65] For a broader view of the Porter's Diamond Model, as well as a revision of such theory to study the G20's renewable energy industry competitiveness, see: K. Fang *et al.*, *Assessing National Renewable Energy Competitiveness of the G20: A Revised Porter's Diamond Model*, in 93 Ren. Sus. Energy Reviews 719-731 (2018).

Japan might be a reaction to the energy dependence of the country on foreign resources. This seems to be the Japanese rationale, as they have encouraged technological innovation to reduce their reliance on non-renewable resources[66]. As for what is stated by the author, to reach energy import dependence, it is essential for Japanese economic and institutional structures to stimulate sustainable innovation.

IV.5 THE SOUTH KOREA CASE

South Korea is characterized by a recent history of green development and innovation, constituting an optimal case study to understand why East Asian countries are striving toward clean innovation[67]. Castellacci and Mee Lie used data from the Korea Innovation Survey 2010 to investigate what factors influence the various types of eco-innovation in South Korea. The authors offer a new taxonomy of green innovation, intended to go beyond the traditional international focus on European countries' clean technology development (in particular, the focus on Germany's *Energiewende*), to offer a new geographical perspective on the debate[68]. Among the main eco-innovation drivers, the authors mention marked demand (especially for recycling technologies), environmental policies and consequent taxes and regulations[69]. The study highlights the great effort of the South Korean government in developing strong climate policies, implemented through an explicit green growth mechanism. As a result, firms have reacted with increasing involvement in eco-innovation, supported by the government rhetoric stressing the positive effect that innovation has on competition. Castellacci and Mee Lie seem to notice for the South Korean case what Zhou *et al.* have put forward for the Chinese one. In fact, both contributions point out the combined impact that legal, governmental, and cultural sub-environments have on the innovation rate of a country. The efforts by the Korean government in advocating for green growth as a virtuous business driver has sensibly impacted the overall clean technological growth of the country. Nevertheless, Veugelers warns against excessively straightforward links between clean governmental policies and private eco-innovation. In his econometric

66 N. A. Venhammar, *Overcoming the Challenges of Energy Scarcity in Japan. The creation of fossil fuel import dependence* (2017), Lund University. Department of Economic History, at 29.
67 F. Castellucci, C. Mee Lie, *A Taxonomy of Green Innovators: Empirical Evidence from South Korea*, in 143 J. Cleaner Prod. 1036-1047, 1037 (2017).
68 *Ibid.*, at 1038.
69 *Ibid.*, at 1046.

study, the author affirms that 'government intervention can [and must] affect private sector innovations, albeit with substantial variation among policy instruments and technologies'. Therefore, there are differentiations to be drawn, as each sub-type of eco-innovation calls for sector-specific institutional drivers (this same conclusion is reached by Castellacci and Mee Lie).

V. INSTITUTIONS INCREASING THE NUMBER OF CLEANTECH PATENT APPLICATIONS

What are the country-specific institutional features that make these nations score high in terms of green innovation, represented by the number of patents? The previous nation-focused sections had the role to depict the framework in which to develop further econometric studies to answer this question. Can we then say that institutions incentivizing patenting in a safe and rewarding environment have an actual impact on the rate of innovation of a country? And does more innovation mean more tools to fight climate change? The issue is undoubtedly complex, involving many different stakeholders influencing innovation, such as 'institutions, culture, policies, infrastructures, education, mediators, financers, research, society, public sectors, business'[70]. As suggested by Cohen *et al.*, besides institutions, other factors are increasing the rate of green patenting, such as the allocation of capital[71]. In addition to the involvement of multiple clean-innovation drivers, green inventiveness does not follow a one-path direction. As previously reported, there is a whole eco-innovation taxonomy that can be developed, with each sub-sector having its own influencing factors. Several studies try to find justifications for such heterogeneity. For example, Leyva-de la Hiz *et al.* partially explained the phenomenon through differences in home-country institutional profiles. What emerges from their study is that several elements are reciprocally influencing each other, as governmental institutions do on industrial organizations. The former affects the latter through environmental policy and regulation pressures[72], whereas the contrary also occurs, when firms lobby for their interests in political contexts[73]. This makes it difficult to draw a distinct line between drivers of innovation to operate sound econometric analysis that could confirm the causal correlation. Another layer of complexity in trying to determine what causes some countries to be more environmentally

[70] Holger *et al.*, *supra* note 61, at 2311.
[71] L. Cohen *et al.*, *The ESG-Innovation Disconnect: Evidence from Green Patenting*, The Harvard Law School Forum on Corporate Governance (2020).
[72] D. I. Leyva-De La Hiz *et al.*, *The Heterogeneity of Levels of Green Innovation by Firms in International Contexts: A Study Based on the Home-Country Institutional Profile*, 32 Org. & Env. 508–527, 509 (2019).
[73] Example provided by Hughes, Urpelainen, *supra* note 58, at 59, with the Association of the German Machinery Industry (VDMA) supporting the introduction of the Renewable Energy Act in 2000.

innovative than others is the geographical factor. The Global North and South, as well as the East and the West of the world, have different needs to satisfy, depending on the growth rates of their economies and the perception of the climate problem[74]. As recalled several times by Castellacci and Mee Lie, most studies concentrate on European samples, whereas sound econometric studies on East Asian countries are still lagging behind. Hence, extending the geographic coverage of empirical analyses on eco-innovation is essential.[75]

VI. FINAL CONSIDERATIONS

Many are the elements to include in the study of eco-innovation and its institutional drivers, and this discussion tried to display the complexity of the topic while providing a guide to navigate through the issue. The analysis started from the consideration of several factors, such as institutions affecting the patenting activity, the use of patents to measure the increasing rate of innovation and the country-specific elements leading to sustainable growth. Is all this the result of a causal series of events? This work aims to be a synthesis of some of the relevant pieces of literature in the field, whereas the need for further econometric studies to assess the causal chain of these drivers is evident. The limitations of this paper due to the lack of a quantitative study leave the door open for additional research. Errors and reverse causality are behind the corner, therefore a careful selection of the methodology and data to execute the quantitative study is required. An example of reverse causality is pointed out by Zhou *et al.*[76] when stating that green innovation is listed among the factors influencing an institutional environment. Are institutions influencing innovation or vice versa? Is it reciprocal? This needs to be considered. Moreover, patents alone cannot be the sole proxy used to measure eco-innovation, first and foremost because they are indicators for inventions, not innovations[77]. This paper is meant to provide a conceptual overview for those wanting to approach the issue, without any pretense to be exhaustive. A CLE methodology applied to all the several stages of the innovation process can help identify the most relevant institutions and their interplay, not only in a national context but with an eye to international

[74] More on the willingness of the North to help the South at: K. S. Herman, *Beyond the UNFCCC North-South Divide: How Newly Industrializing Countries Collaborate to Innovate in Climate Technologies*, in 309 J. Env. Mgmt. 114425 (2022).

[75]

[76] Zhou *et al.*, *supra* note 50, at 2.

[77] Kempt, Pearson, *supra* note 46, at 103.

counterparts[78]. As an example, both Germany and South Korea seem to have strong governmental policies (governmental sub-institutions) in favor of green innovation. Under the CLE lenses, it is possible not only to highlight the similarities between the two legal systems, but also to go one step further and use a comparative approach to all the phases of the policy process, from agenda-setting to termination[79]. Another fruitful avenue for research could be to assess to what extent comparative law could help less green innovation performing governments draft sound and effective policies that could spur more eco-inventiveness. A further line of continuation of this work could also be to verify two major questions: (a) Does more green innovation mean a more effective fight against climate change? (b) What are the main methodological issues related to legal transplants of green innovation and how could they be resolved? Hopefully, these considerations will have broader implications in the process of understanding what determines innovation in a country and what could be done to virtuously imitate the best- performing ones. One last point needs to be mentioned: although a common CLE methodology has yet to be drafted[80], at least this approach can aim to provide a general framework in which different stakeholders can start an interdisciplinary dialogue to address global issues, such as environmental innovation to fight climate change.

[78] For more on comparative legal diagnostics see Bellantuono, *supra* note 16.
[79] *Ibid.*, at 4.
[80] *Ibid.*, at 8.