A Systematic Review of Knowledge Spillovers from Renewable Energy Technologies (Rets) in Cameroon

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Abstract: Increases in the atmospheric concentration of carbon have significant adverse environmental and socio-economic implications, more so for developing with little climate-centric infrastructure. This paper investigates the salience of renewable energy in addressing climate risks and forming the basis of an innovation-centric growth model. It analyses the prevalence of knowledge spillovers in Cameroon using patents as a proxy for innovation and drawing from a broad-based international literature spanning 1970 – 2019. The study finds a propensity for knowledge spillovers, which occur from renewable energy to innovation due to learning-by-doing. Additionally, spatial distributions of knowledge clusters are found to result from tacit circulation of technological information within and across industries. The paper finds the need for policymakers to prioritize climate-centric infrastructure to lessen environmental externalities and redress socio-economic and regional imbalances. Meanwhile, second-round effects will incite cross-industry applications from Renewable energy technologies (Rets) and achieve broader development and socio-economic objectives ranging from poverty reduction, innovation and sustainable economic growth.

Introduction

The energy sector is a cornerstone for economic development, improvements in standards of living, and broad-based economic growth in developing economies. Whilst information and communication technologies (ICT) are seen as foundations for economic growth, their prevalence and competitiveness are contingent on access to energy for manufacturing, transport, tourism, and higher value-added sectors that form the basis for sustainable growth (Munuera, Dubbeling & Mueller (2017). Indeed, such a process is symptomatic of energy-dependent economic activity; several studies detail the adverse environmental effects of increases in the atmospheric concentration of carbon, driven by polluting activities that support economic growth and prosperity (Meansah, Ssali & Du (2019), Fakhri, Toumi, and Touili (2015) and Saidi and Hammami (2015)). This is especially so for commodity exporters, a majority of whom have not met the precondition for technology-driven economic development.

Furthermore, renewable energy supports economic growth by limiting energy imports (Valentin 2011) and (Mahapatra et al., 2009) find renewable energy such as wind, solar, biofuels, hydroelectricity, and associated technologies to generate health and environmental benefits along with the facilitation of energy access for industries and households. Several studies spanning the Johnstone and Haščič, (2010), Ragwitz et al. (2006), and Edenhofer and Stern, (2009) find renewable energy to have positive impacts on employment, sustainable economic growth with positive spillovers into industries spanning manufacturing to higher value-added products and services.

Advances in technology are a 'force majeure' in facilitating the transition away from fossil fuels as they lower energy cost, support nascent industries and cause greater market penetration of renewable energy and associated technologies (Ponelis and Holmner, 2015). Consequently, technological advancements in renewable energy will accelerate the energy transition.

Cheaper and more accessible renewable energy technologies (Rets) will become more efficient and adopted across various industries (Braun et al. (2010) and Acemoglu et al. (2012). Additionally, the rapid adoption and diffusion of renewable energy will become increasingly apparent across the industrial and manufacturing sector, facilitating the emergence and development of higher value-added products set to drive long-term competitiveness across for consumer and non-consumer products, auto manufacturing, ICT components, and industrial chemicals. This is particularly salient for developing economies like Cameroon, with raw materials accounting for 65.0% of total exports, intermediate goods at 13.0%, and capital goods at 1.58% (World Integrated Trade solutions, 2020). For the CEMAC region, comprised of Cameroon, Central African Republic, Republic of Congo, Chad, Equatorial Guinea, and Gabon, oil accounts for about 20% of GDP (International Monetary Fund, 2019).

An increase in the renewable share of the energy mix will boost productivity by lessening the adverse effects of power outages on economic growth, whilst the transmissions from renewable energy and relevant technologies will reduce carbon emissions and expedite higher value-added exports to drive sustainable and inclusive economic growth. Moreover, the creation of an "innovation milieu" triggered by the transmissions of renewable energy into innovation is consistent with findings of knowledge diffusion from innovation by Cooke & Morgan (1990) and Scott (1988). Furthermore, the knowledge generated from renewable energy technologies (RETs) is captured by companies other than knowledge-generating firms (Noailly & Shestalova (2013).

By employing a qualitative approach, this study examines the extent of knowledge spillovers from RETs as innovative ideas spill over into firms and sectors, generating what can be otherwise termed as "positive externalities". This paper investigates the contention that renewable energy facilitates the emergence of knowledge clusters can lead to faster economic development. Drawing from broad-based international literature spanning Popp (2002), Van der Zwann, et al, (2009), and Popp & Newell, (2012) and cross-sector applications of RETs, the study finds positive spillovers from renewable energy and associated technologies into the industry, with cross-country spillovers facilitated by international trade.

The salience of a qualitative approach shows heterogeneity in the adoption of renewable energy as well as labor market differentials and human capital determine the rate of pass-through from RETs. The findings, therefore, contribute to the literature from Fabra et al. (2015), Ibenholt (2002), Klaassen et al. (2005), Krammer (2009) and Söderholm & Klaassen (2007), whilst accounting for the possibility of a "leap-frog" in developing economies. Admittedly, the pass-through from technological advancements in the energy sector are driven by photovoltaic, the technology and software powering wind turbines and solar farms as well as lithium-ion batteries and carbon fiber (Bloom et al. (2013), Corsatea (2014) and Jamasb & Politt (2011)).

As such, Newell (2009) posits that innovation improves costs and efficiency, although the IRENA (2017) shows that innovation enables the integration of existing and emerging renewable technologies. Regardless of whether early-stage renewable technologies become available, their ability to increase energy efficiency and distribution suggests bi-directionality from innovation to renewable energy and vice versa (Johnstone et al. (2009). Indeed, international experience suggests a less than the marginal impact of renewable energy and associated technologies to innovation (Aalbers et al. (2013) and Nordhaus (2007)). However, renewable energy will facilitate sustainable economic growth, generate technology spillovers via learning-by-doing, and drive broader competitiveness (Clarke and Weyant (2002) and (Dechezleprêtre et al. (2013)). The rationale for the energy transition away from fossil fuels is justified and the economic benefits provide credence to the persistence of a relationship between renewable energy and technological advancements.

The study is divided as follows; the second chapter provides a review of the literature, Chapter three discusses the energy situation in Cameroon. This is followed by a methodology in Chapter three. The findings are discussed in conjunction with findings from the literature in Chapter four. The study concludes with recommendations in chapter five.

Literature review.

The environment-growth-nexus suggest heterogeneity in the transmission mechanisms from renewable energy such as solar, wind, marine, hydropower, geothermal, waste, and biomass energy technologies and the knowledge from storage technologies to innovation and growth. Whilst a great deal of the literature details the anthropogenic causes of climate change (Johnstone & Haščič, (2010), authors such as Nordhaus (2007) posits that increases in the atmospheric concentration of carbon have caused negative externalities to accrue to climate outcomes. The environmental, economic, and social impact can be attenuated with the adoption of renewable energy, while the transmissions from RETs into innovation will have more persistent effects on standards of living, economic growth, and carbon emissions. A plethora of studies such as Brusco (1990), Sabel (1989), Camagni (1991) and Maillat & Vasserot (1988) investigate the transmissions and knowledge spillovers from storage technology, solar, biomass, and hydropower, marine and waste energy and associated technologies (Tchouaha, 2012). Rather than reflect lower energy cost, the spillovers are much more broad-based across renewable energy as storage technologies determine rates of adoption as well as management of the grids.

Dechezleprêtre et al. (2013), find that innovations in clean energy generate spillovers from production, automobiles, fuel, and lighting. Their findings show patented inventions receive 43% more citations than dirty inventions, thus supporting the view that stronger public support for clean R&D is warranted. Meanwhile, Nemet (2012) finds that valuable advances in energy technology suggest that knowledge acquired from external sources has a positive effect impact on energy inventions. Noailly & Shestalova (2013) investigate intra-technology spillovers of knowledge flows within similar technological sectors, technologies in power generation termed inter-technology spillovers, and external technology spillovers using citation data of patents in renewable technologies at 17 European countries over the 1978-2006 period. The results show heterogeneity across various renewable energies, solar energy and storage technologies find applications in sectors other than power generation, suggesting higher spill over into the real economy. Conversely, the technological advancements in wind energy are constrained to the power sector. This work chimes with findings from Dekker et al, (2012).

Over the years, two main strands of literature investigate the knowledge spillovers from energy technologies. The first strand of the innovation spillover literature estimates knowledge spillovers based on the effects on the current or available stock of knowledge on renewable energy technologies and current innovation outcomes. By investigating patents in eleven different categories of energy technologies, Popp (2002) finds evidence of significant intra-technology spillovers in solar and wind technologies to be statistically significant across the studied categories of technology. The results align with evidence from Johnstone and Haščič (2010) whose findings of inter-technology knowledge spillovers show that knowledge stock, which accrues to storage technologies, has a net positive impact on innovation in renewable and clean technologies, more so for intermittent technologies. This article fits into the first category of the literature, using data on patents and renewable energy generation to investigate the extent of spillovers from renewable energy and associated technologies into innovation such as Dechezlepretre, Martin and Mohnen (2017), Trajtenberg, Jaffe and Fogarty (2000), Caballero & Jaffe (1993), Jaffe, Trajtenberg & Henderson, (1992) and Söderholm & Klaassen, (2007).

Similarly, Braun et al. (2010) find significant intra-technology spillovers from wind and solar innovation across a representative sample of firms. Nevertheless, the spillovers in wind technologies seem to be apparent in the field of energy machinery, giving credence to the literature from Dechezleprêtre, Martin & Mohnen (2014) find significant inter-industry spillovers. These studies contribute to the literature by focusing on the effects of the knowledge stock accumulated through the life cycle of projects on future innovations. According to Nemet (2012), the exogenous implications of inventions and innovations outside renewable energy cannot be understated, suggesting directionality between innovation and renewable energy. By using citations from inventions and knowledge originating from other sectors, the study finds palpable spillovers from innovation into the energy sector.

Popp and Newell (2012) use citations to investigate the value-added from innovation gains and spillovers in non-energy technologies. The investigation into the social value of research and development correct for factors that affect the likelihood of citations find energy patents to be more general than other patents and, also, more likely to be cited. There is a less than the marginal probability that energy patents contribute to a broader set of patent classes, in comparison to other general-purpose technologies.

According to Dechezleprêtre et al. (2013), clean inventions generate substantially more knowledge spillovers than dirty inventions. Their findings show that clean patented innovations tend to be cited 43% on average than inventions in the fossil-fuel sector, giving credence to the view that stronger public support for clean R&D is warranted. As such, the literature is also relevant in the context of public R&D within the energy sector (see Aalbers et al., 2013, for discussion) as CEMAC governments hold a significant share of domestic energy companies.

Chen and Lei (2018) consider individual heterogeneity and overcome omitted bias use quantile regression to estimate the determinants of CO2 emissions; they find the impact of renewables on high emissions countries to be much more muted due to a smaller portion of renewables such as wind, solar and biomass in the energy mix. Nevertheless, technological innovations have less than a marginal impact in countries with high CO2 emissions. Technological change, according to Groba and Breitschopf (2013), reduces the cost of technology and increase penetration as policy interventions reduce the relative price by incentivizing innovations in green technology. Furthermore renewable technological innovation drives international competitiveness via efficiency gains in inputs such as solar nodes and integrated circuits.

The challenge of integrating high shares of variable wind and solar into the grid influences innovation in renewables from the demand and supply-side as per Martinot (2016). For the former, demand for renewable energy storage technology and electric vehicles incentivizes innovations in transmissions and distribution networks as well as grid operators. Indeed, decarbonizing to limit global temperature increases to well below 2.0% will lead to stranded assets, the accelerated deployment of renewables will limit the adverse financial effects during the transition period. According to Aschalew (2017), the deployment of climate technologies needs to be sustained in other to support systems transition towards renewable energy.

According to Feriol et al. (2009) and Nurcan (2018), learning-by-doing may impact the overall costs of technology, but the aggregate form of learning could be better explained by improvements in single components. They find that cost reduction is unlikely to persist and is therefore prone to limiting the impact of cost-centric improvements. Renewable energy nonetheless causes innovation as positive feedback loops from R&D trends in green and storage technologies (Kobos et al., 2006).

Additionally, a study by Isoard and Soria (2001) finds that learning at an industry level tends to drive productivity growth. The latter is further emphasized by Camagni and Capello (1997). At the core of the literature is the innovation milieu that facilitates transmissions from technology to human capital and industry. Whilst several mechanisms exist to that regard, Söderholm & Klaassen (2007) support the abatement of archaic technologies for process innovations. These occur through synergetic build-ups of innovative capacity and a collective learning process.

Learning by doing (LBD) as transmission mechanisms from innovation

Other studies suggest two competing effects. On one hand, there is the added value to near-term technology investment due to LBD, as just mentioned. On the other hand, LBD also leads to lower costs of future abatement, which implies that abatement should be delayed. The net result of the two opposing effects may be theoretically ambiguous, but numerical simulations by Ek and Söderholm (2010) suggest that the slope of the abatement curve over time actually may be steeper with LBD included, contrary to previous findings, such as those of Grübler and Messner (1998). In the R&D model, there are two effects of induced innovation on optimal abatement: it reduces marginal abatement costs, which increases the optimal amount of abatement. But it also increases the cost of abatement today relative to the future as marginal utility effects set in. Conversely, Dechezleprêtre et al. (2013), posits such outcomes appear probable because of lower abatement costs in the future are driven by cost and productivity efficiencies

The combination of these effects implies that with R&D-induced innovation, optimal abatement is lower in the early years and higher in later years than it would otherwise be. In contrast, in the LBD model, there is a third effect: abatement today lowers the cost of abatement in the future. This reinforces the tendency for cumulative optimal abatement, which tends to be higher in the presence of induced innovation but makes the effect on optimal near-term abatement ambiguous. Bramoullé and Olson (2005) formalize the relationship between learning and policy, noting that if technology improves by LBD, marginal abatement costs are equal across time. This brings human capital to the fore as playing an indispensable role necessary for RET diffusions, with path dependence and new use of technologies as the most central determinants of RETs spillovers within the energy and non-energy related industries.

As the energy sector faces long-term structural changes as planning, and operations including grid monitoring, Martinot (2016) argues that these will likely be assuaged by technological advancements. This suggests a pass-through from renewable energy to innovation, with the latter contingent on the life cycle of renewables. Kobos et al. (2006) also investigate the price implications of learning-by-doing, learning-by-searching (cumulated R&D spending), and innovation. The results show that the R&D expenditure linked to renewable energy is indispensable to innovation and should be included in the learning process.

Consequently, the role of environmental policies in driving long term competitiveness, sustainable growth, research efficiency, and conservation are indispensable to ensure an enhanced understanding of the transmissions from RETs to innovation. Whilst a bi-directionality is not completed averted in the literature (Maruseth and Verspagen (2002), Lanoie et al. (2011) and Johnstone et al. (2009)), the relationship, nonetheless, suggests a need to investigate the implications of RET adoption on innovation in Cameroon. Not only is Cameroon is highly exposed to climate change, transitioning to renewable energy could spill over into other sectors. This paper investigates the propensity for such spill overs by investigating a broad international literature.

Chapter 3. Energy Production in Cameroon

The major sources of energy supply in Cameroon include Petroleum, coal, and hydropower with over 90% of the residential sector using traditional fuels for light, heating, and cooking (Abanda et al. (2016)). Various estimations suggest access to electricity ranges between 65% and 88%, although only 14% of the population has access to electricity according to Djouedjom, Francine & Andrew (2018), with three separate grids i.e. the Northern Interconnected Grid (NIG), the Eastern Isolated Grid (EIG) and the Southern Interconnected Grid (SIG). Cameroon is a net exporter of energy due to its oil reserves (Fogue, Hamandjoda, and Tatietse, 2011).

The renewable potential in Cameroon remains largely unexploited, with only a meager fraction of hydroelectricity used with developments of commercial solar ventures at a nascent stage in the renewable lifecycle. The North and southwest parts of the country have solar radiation of 5.8 kWh/day/m2 and 4.5 kWh/day/m2 (Abanda et al. (2016). There are currently 50 PV installations through distributed generation systems and the sector is poised to grow in the coming years, with investments in renewable energy rising, albeit tepidly. Cameroon signed its first Memorandum of Understanding with Green quest Solar Corporation, for a photovoltaic installation of 500 MW (Mbodiam, 2018). The 2020 photovoltaic project will be located in the North and the first stage entails a 72 MW PV plant; the contribution to the overall energy supply from said project will be marginal at best, there will be significant positive spillovers in macroeconomic, health, and wage outcomes. (Tansi, 2011).

Coastal and Northern areas are conducive for wind energy, with speeds of 5-7 m/s in coastal areas and 2-4 m/s above 100 meters. There are currently two wind turbines installed in the Littoral province, Douala and feasibility studies are being conducted for a 42 MW wind energy project, which could be extended to 80 MW (Abanda et al. (2016). Similar projects are also underway in the Bamboutos Mountains in Eastern Cameroon. Cameroon generates more hydroelectricity than most African countries, after the Democratic Republic of Congo and Ethiopia. Out of the 23 GW potential, equivalent to generating capacity of 115 TWh per year, less than 5% is currently being exploited Admittedly, the Lom Pangar (30 MW), Memeve' ele (210 MW), Nachtigal (420 MW) are the three largest projects currently under operation ((Tchanda et al, 2000).

Additionally, a significant bioenergy potential is present in Cameroon, with the forest covering almost 50% of the country, the largest biomass potential in sub-Saharan Africa (Katerere Minang and Vanhanen, 2009). It is the most widely used source of fuel for electricity, lighting and comprises one of the highest pollutants. More so, for coastal areas that are most exposed to rising sea levels, with 1.8 million people exposed to floods. Cameroon currently holds the potential for 37 sites in 9 regions despite not taking part in the commercialization of biofuels and its emissions per capita is on a steady uptrend (World Bank (2020). Meanwhile, there are avenues to leverage hot springs, currently residing in Manengoumba area, Lake Moundou, and Ngaoundéré (Tchouaha, 2012).

Cameroon stands to benefit from investments in Renewable energy as its climate and location make it uniquely placed to exploit renewable energy. (Tchanda et al, 2000). Cameroon is a member of the Central African Power Pool (CAPP), a group of central African states that seek to align common energy policy and monitor the construction of infrastructure in countries whose electrification rates are below 20% (CAPP, 2020). This will facilitate the diffusion of innovation and learning-by-doing will increase adoption across industry (Njomo & Nkue (2009) and Mboumboue (2016).

Chapter Four: Methodology

This article investigates the impact of RETs on technological advancements and innovation in Cameroon. In an attempt to decipher the transmission mechanisms from renewable energy to innovation, it employs a qualitative bi-directional approach, using a mix of patents consistent with Dekker et al (2012), Johnstone and Haščič (2010), Braun et al (2011) and Noailly & Smeets (2013). Due to the lack of high -quality data on innovation and the limitations stemming from a constrained time series, the study is limited to 8 years spanning 2011 and 2018 and it compares the number of renewable projects undertaken during the specified period, with investments in renewable energy. The sparse data from the World Intellectual property Organisation is limited to general patents, which can nonetheless serve as a gauge for the extent of transmissions, consistent with Popp (2002).

The study also employs a qualitative approach and determines the appropriateness of methodologies, using feasibility studies to ascertain the pass-through from the adoption of renewable energy and technologies to innovation. Furthermore, the study draws from global literature spanning 1982 – 2019 to improve the robustness of the findings, with recommendations designed to reflect Cameroon's macroeconomic and climate backdrop.

Based on the findings from Griliches (1990) and Popp & Newell (2012), patent data provide more disaggregated information on innovation, hence a fitting indicator to measure the transmissions from renewable energy. Furthermore, patent applications culminate improvements in productivity, and innovation tends to be output-oriented. As such, the rationale for a quantitative methodology on innovation proxied by patents and industrial designs gain credence from the literature and allow for a country-specific approach given the absence of high -quality data with sufficient granularity to support a time series analysis.

Chapter Five: Data analysis and recommendations

Due to its size, geographical location, and capital needs, Cameroon has attracted a mix of foreign direct capital and development assistance – by way of loans – to fund green and renewable infrastructure. One such project is the Lagdo power station in the Northern Region. The 20MW solar plant is developed by Chinese Sino hydro, stemming from a memorandum of understanding between the company and the Ministry of water and energy (Ngouno, 2016). The project is designed to address the declining levels of output and the aging Bini hydroelectric dam, whose falling output supplies three northern regions in Cameroon. Whilst poor governance leaves little in terms of employment numbers, a conservative analysis of employment prospects based on population densities suggest knowledge transfers are not unlikely for 600 green sector employees in the region, who are likely to benefit from capacity building events, a standard for externally-sponsored projects. According to

Aschalew (2017), technology transfers are contingent on rates of adoption as regards solar energy, learning by doing facilitates knowledge transfers from process innovations (Jamasb & Politt (2011), Corsatea (2014) and Dechezleprêtre et al. (2013) and create the basis for indigenous innovations in the future.

As illustrated in Figure 1, there was a marked drop in the number of both resident and non-resident patents between 2016 – 2017. While these periods saw significant investments in the renewable sector and an improvement in the infrastructure, there appears to be a substantial increase in the number of recorded patents, which suggest that gains in innovation likely occurred with a lag as seen in the less than a marginal increase in the total number of patent applications in 2018. Indeed, the lag in rates of diffusions from process innovations is driven by the heterogeneity of labor markets, human capital, and innovation absorption capabilities proxied by supportive infrastructure. It follows that the lag emanates from the time at which innovation is perceived as the informative and broader innovation outcomes as Adarsh et al. (2018) and Ek and Söderholm (2010) posits. Neely and Hill (1998) posit that rates of diffusion are contingent on the absorptive capacity of the organization and barriers stemming from resistance to change, rigid organizational arrangements, and conservatism. As such, the rates of diffusion are contingent on the availability of human capital, which will determine the extent of intra-industry and inter-industry spillovers.

Furthermore, external barriers such as inappropriate legislation, ill-suited for largely untrained, and non-digitized workforces also stymie the adoption of innovation (Tchanda et al, 2000). As such, policymakers should emphasize an innovation-centric approach to labor market policy, which prioritizes technology and skills transfers beyond capacity building events. Such an approach, whilst suited to the current skill-level of the workforce, will encourage increased adoption rates of innovative practices. Meanwhile GDS Orion Solar is a joint venture by French General du Soleil and financial partners such as Arborescence Capital investment fund are set to build a 20 MW solar power plant in Ngaoundere, the capital of Adamawa (Mboumboue, (2016). Similarly, Refela-Cam is building sustainable projects designed to boost energy output, reduce environmental degradation, and improve energy access for areas that are not sufficiently served by the grid. The installation follows a network-based approach with technical training sessions designed to support the street lighting system that relies on solar energy in Bangante and Fokoue. Such an approach emphasizes the transfer of technical know-how and faster rates of innovation pass-through, whose spillovers are more widely felt in the maintenance of the infrastructure and probable transmissions to other sectors more prone to technological adoption. Such an approach could form the basis for an innovation-driven model of economic development posited by Schumpeter (1934), although positive spillovers consistent with Ek & Söderholm (2010) and Kobos et al. (2006).

Innovation "milieus" and regional spillovers

A growing body of findings at the core of the literature suggests the prevalence of an "innovation milieu" comprising a network of relationships and interlinkages within a geographic area, that facilitates innovation sharing and the development of capacity occurring through a synergic process of learning-by-doing, as argued by Camagni & Capello (1997) and Isoard & Soria (2001). This culminates what can be pithily described as a "manoeuvre approfondis" from spatial networks that limit the intensity and extent of intra-industry and intra-regional spillovers, which is consistent Yang & Andersson, (2018). The regional spillovers from the 20 MW solar power plant in Ngaoundere and Lagdo power station in the Northern Region suggest an increased probability of an innovation milieu, facilitated by the emergence of supply chains in the innovation milieu.

A natural consequence of innovation spillovers is natural concentrations of economic activity, which gives credence to a decentralized approach to innovation pass-through, consistent with Nkue & Njomo (2009). Given the current labor force is ill-equipped to facilitate the spillovers from RETs in the short-term (Takoyoh, 2003), a decentralized approach will improve cross-sector synergies from emerging within RET clusters.

Furthermore, several studies outline reduced transport costs, a larger labor pool, and knowledge spillovers for regional and spatial distributions of knowledge clusters (Krugman (1999) and Rotemberg & Saloner (2000)). In the context of Cameroon, such an outcome will lessen power outages, which impede economic development and support nascent higher-value-added sectors such as apparel and other assembly-related industries such as ICT components and industrial manufacturing. Meanwhile, territorial production systems, driven by industrial districts and innovation create a "milieu" that facilitates innovation pass-through. Authors such as Sabel, (1989), Maillat and Vasserot (1988), Cooke & Morgan (1990) concur, which in turn this explains the prevalence of renewable energy plants in Douala, the economic capital nonetheless.

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Renewable energy and Innovative capacity

According to Scott, 1988 innovation capacity refers to innovative capability, competence, and absorptive capacity improving the ability of a region to innovate, business, and innovation performance Lawson & Samson (2001). In the context of renewable energy, the absorptive capacity dictates the extent of knowledge spillovers into non-energy sectors. There appears to be no suitable authoritative definition regarding the ability to innovate. The potential of a firm, region, or nation generate outputs are simply derivatives of innovation capacity, technology, and knowledge spillovers into non-energy sectors. As such, the complexity of renewable energy suggests a greater propensity for spillovers to support industry and supporting the broader innovation ecosystem. As such, industrial designs will likely rise in tandem with increased energy access as RETs spill over into non-energy sectors (Noailly & Shestalova (2013).

The presence of knowledge clusters is a pre-requisite to absorptive and disruptive innovative capabilities. The Emerging Africa infrastructure fund has provided an 18-year credit line for a hydropower station in Sanaga, littoral province. The €120 billion plants are poised to produce 420 MW to the southern grid, with 1500 jobs created throughout the infrastructure spanning installation, security and allied services, safety, and communications. Furthermore, the latter is currently powered by solar culminating 50 PV installations, which suggest inter-industry and intra-industry spillovers engineered by natural competitive pressures and price-centric competition. The probability for knowledge and technology spillovers are much more likely due to learning-by-doing (Mir et al., (2016)) that inevitably results from a large portion of the workforce employed in renewable projects.

Learning by doing facilitates the transmission mechanisms from renewable energy

R&D-induced technological change tends to differ from learning-induced technological as the models used in the concept of learning-by-doing (LBD) suggest a decrease in manufacturing costs unlike learning by using, which appears to be a function of technology as argued by Arrow (1996) & Rosenberg (1982). Renewable energy ultimately comprises technologically-driven improvements derived nonetheless from R&D.

As such, the false sense of comfort derived from economic modeling as argued by Clarke & Weyant (2002) is averted as this article emphasizes learning by doing approaches, which are quantifiable based on the number of people employed in any given renewable project such as the Natchigal hydropower project on the Sanaga. Whilst R&D expenditure is needed, carbon-free technologies lower the cost of technology in the future, leading to fewer emissions and a faster rate of transmissions from renewable technologies via learning-by-doing (LBD). The optimal abatement path needed to reach concentration involves knowledge spill lovers evident in LDB and abatement at a later stage of the cycle is less, argues Grübler & Messner (1998). This occurs because abatement over the near term incentivizes LBD in renewable energies, which in turn lowers the long-term abatement cost and accelerates the rates of transmission from technologies. Van der Zwaan et al. (2002) also find a strong effect of LBD, which inadvertently results in cost-saving over the medium to long-term.

Whilst innovation can be produced by one enterprise in the context of renewable energy projects, innovation occurs as a result of interdependencies between extra-territorial and territorial elements. Crevoisier et al. (1991). Given the milieu of technological innovations suggest a collective process of learning reinforced by international technology transfers, it at once reinforces a new exploitative innovative behaviour, which suggests a less than marginal transmission from renewable energy and associated technologies to innovation. The renewable energy projects outlined in the study have seen both patents and industrial designs average 30.75% and 40% between 2011-2015 and 2016 – 2018, while the latter averaged 27.5% and 35.3% between 2011 – 2015 and 2016 – 2018 respectively (Table 1).

These have aligned with an increase in renewable projects in the last 5 years and the lag from earlier investments suggests a possible pass-through from renewable energy to innovation, consistent with findings from Isoard & Soria (2001) and Grübler and Messner (1998). Nevertheless, their findings are limited to knowledge spillovers, which suggests an approach to diffusions of RETs via learning-by-doing (Ek & Söderholm (2010). The viability of such an approach rests not solely on the types of renewable energy and associated technologies adopted but on the mechanisms designed to facilitate increased rates of adoption across CEMAC member countries.

The concept of 'innovative milieu' has led to a new perspective of explaining innovative behaviour. The milieu restores the importance of social elements in explaining the process of innovation, which facilitate the transmissions from Rets. As such innovation is now seen as a collective learning process reinforced by "such social phenomena as an intergenerational transfer of know-how, imitation of successful managerial practices and technological innovations, interpersonal face-to-face contacts, formal or informal cooperation between firms, and tacit circulation of commercial, financial or technological information (Camagni & Capello (1997).

Public policy should emphasise a transition towards renewable energy

Consequently, public policy should emphasize the need to transition towards renewable energy such as wind and solar farms as well as biofuels, whilst phasing out fossil fuels such as crude oil and natural gas at a faster pace due to the adverse health and environmental effects.

Furthermore, Tchouaha (2012) finds fossil fuel subsidies to be economically counterproductive and environmentally dangerous as Cameroon is at once exposed to extreme climate risks. Cameroon's current account deficit and non-oil balance of payment are poised to average 3.1% and -2.9% between 2020 – 2024 from 3.2% and -5.3% respectively between 2016 – 2019. The slight improvements in its fiscal position are contingent on high oil prices, which is unlikely as China is growing at a slower pace as its economy transitions from an investment-led to a consumer and innovation-driven economy. Meanwhile, the EU and UK plan to decarbonize their economies by 2050, which will dent the global demand for fossil fuels, increasing the risk of a financial crisis and slowing the pace of economic development. As illustrated in the literature, developing economies stand to benefit from targeted environmental regulation, public-private partnerships as well as the transition towards renewable energy.

Rather than rely on FDI investment in fossil fuel sectors, policymakers should prioritize investments in renewable energy, off-grid solutions in rural areas as well as components such as string inverters, racking, and batteries for solar panels as well as ICT-hardware for wind farms. Furthermore, by optimizing our investment screening policies to attract investment in green technology and creating disincentives for carbon shifting, social dumping, or green washing, policymakers can accelerate the adoption and deployment of green technology.

Public policy should support new entrants in domestic technology and energy companies that can facilitate the transition to renewable energy. This will ensure substantial technology and knowledge transfers from renewable RETs to innovation across the economy in various i.e. learning-by-doing and learning-by-sharing as argued by Kobos et al. (2006). Admittedly, the risk of cumbersome environmental innovation can stymie innovation and adoption over the long run, but Antweiler et al. (2001), Harris et al. (2002), Grether & de Melo, (2003) and Jug & Mirza (2005) find the absence of consensus on the impacts of environmental regulation on innovation. Targeted environmental policy will support productivity and international competitiveness (Braun et al. (2010).

Whilst Cameroon does not currently export green technology, regulation should facilitate public-private partnerships to ensure sufficient technological transfers from the private sector to the public sector. This provides credence to the argument that renewable energy policy should be designed to facilitate the pass-through from green energy and technology to innovation. Additionally, Johnstone & Haščič (2009) and Maruseth and Verspagen (2002) uses patents as a proxy for innovation, finds R&D spending to have a positive impact on renewable energy, suggesting the probability for bi-directionality in the adoption of renewable energy.

The adoption of renewable energy will have a long term impact on innovation as producing and scaling-up renewable energy requires sufficiently skilled human capital as well as technologies spanning machine learning to forecast energy demand and supply, artificial intelligence to map spatial trends in energy consumption and robotics to monitor grids or facilitate the adoption of high power transmission grids (Nkue, Njomo & Donatien (2009) and Tchouaha S. (2012). By transitioning to renewable energy at a faster pace, the employment shock that inevitably results from energy transitions will be assuaged over the short term by targeted public policy. Policymakers should prioritize the adoption of new technologies in other to increase energy security, reduce structural vulnerabilities in the energy generation and incentivize the adoption of green energy by consumers (Joseph, Medard, Oumarou & Thomas. (2011) and Takoyoh. (2003).

RETs will support nascent manufacturing industries

Furthermore, renewable energy will reduce power outages, which will support the development of the manufacturing sector. Cameroon is currently a net commodity exporter, with a bulk of its exports comprising mineral fuels including oil (45.0%), Cocoa (14.6%), wood (17.0%), and Gems and precious metals (9.2%) (WITS, 2020). Renewable energy and associated technologies will not only improve access to energy, rates of mobile phone penetration, and internet access. These will digitize the workforce, create new innovation milieus (Yang & Andersson (2018) and Krugman (1999) and facilitate LBD as outlined by Kenfack et al. (2011) and Njomo (2000). Said advancements could facilitate the adoption of advanced technologies such as machine learning and artificial intelligence to manage the grid, which achieve dual objectives of addressing climate risks and the transmissions from RETs.

Domestic regulation should address social dumping ad prioritize learning-by-doing

Given the current pace of technology adoption across emerging markets, countries such as Cameroon are increasingly exposed to carbon and social dumping, which suggest a probable transfer of negative externalities from technologically advanced economies that are poised to decarbonize by 2050 for the European Union and the United Kingdom (European Commission, 2020, BEIS, 2019).

Targeted domestic legislation will reduce the likelihood of social dumping and attract greed FDI flows, which are indispensable to economic development as well as a framework for an innovative ecosystem across health sciences, advanced materials, 3D printing, and software. Whilst the backdrop for sufficient diffusion in oil prices are indispensable to diffusion across the workforce and industry, renewable energy allows the creation of innovation milieus with competitive pressures fuelling innovation over the long run.

Conclusion

This article investigates the impact of the adoption of renewable energy and associated technologies on innovation in Cameroon. Rather than proxy innovation by investigating the effects of wind and solar-powered grids on patents and renewables, the literature is a synthesis of empirical and qualitative studies that investigate the relationship between RETs and innovation, learning by doing, and the emergence of an innovation milieu. The latter benefiting from inter and intra-industry spillovers.

The literature posits a pass-through from renewable energy and associated technology to innovation. This occurs via learning-by-doing that leads to the creation of knowledge clusters. As such, public policy should attempt to reduce structural impediments posed by a semi-skilled workforce, with learning-by-doing prioritized to ensure the workforce is sufficiently digitized to facilitate increased rates of adoption.

This paper attempts to answer two questions. Does renewable energy boost innovation via knowledge spillovers? Can learning-by-doing facilitate cross-industry spillovers that at once redress climate vulnerabilities and achieve broader socio-economic objectives? By investigating an international literature on renewable energy and knowledge spillovers, the study finds statistically significant relationships for the said relationship amongst a global sample. It investigates the prevalence of said trends in Cameroon by analyzing renewable energy projects and changes in registered and administered patents. Whilst the absence of granular data suggest less specific findings, the creation of "innovation milieus"

The findings suggest a positive effect from RETs and innovation, with implications for industrial competition. Using a mixed approach, the findings advocate targeted policies that enable public and private sector companies to leverage machine learning to forecast and supply energy production and distribution, robotics to monitor the grid and facilitate the transition of renewable energy spanning wind, solar, biofuels, and hydroelectric power. All these will be driven by the pursuit of learning-by-doing, which facilitates the adoption of RETs across other sectors. Such an approach will reduce the adverse impact of climate change, increase the positive net spillovers across manufacturing, green technology, health care, and the service sector where value-added is linked to energy access

Furthermore, increased internet access will increase rates of digitization ensuring the emergence of innovation milieus that fully benefits from improved energy security. While the economic case for the energy transition remains unchallenged by most, it must occur against a backdrop of an increasingly skilled labor force to leverage technological advances effectively; hence the need to ensure targeted policies to reduce the employment shocks from event-driven shocks. Increased adoption of renewable energy will spillover to non-energy sectors and the transmissions to industry will achieve broader macroeconomic objectives via knowledge clusters.

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List of figures.

Figure1: Patents Application in Cameroon

Figure 2: Industrial Application by Count