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The renewable energy policy Paradox

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ABSTRACT

One major avenue for policymakers to meet climate targets is by decarbonizing the power sector, one component of which is raising the share of renewable energy sources (renewables) in electricity generation.

However, promoting renewables –in liberalized power markets– creates a paradox in that successful penetration of renewables could fall victim to its own success. With the current market architecture, future deployment of renewable energy will necessarily be more costly and less scalable. Moreover, transition towards a full 100% renewable electricity sector is unattainable. Paradoxically, in order for renewable technologies to continue growing their market share, they need to co-exist with fossil fuel technologies. Ignoring these findings can slow adoption and increase the costs of deploying new renewable technologies.

This paper spots the incompatibility between electricity liberalization and renewable policy, regardless of the country, location or renewable technologies. The Paradox holds as long as market clear prices with short term marginal costs, and renewable technology's marginal cost is close to zero and not dispatchable.

1. Introduction

Renewables with negligible marginal costs of dispatch – such as solar or wind – could fall victim to their own success after capturing large shares in liberalized power markets. Given existing liberalized market structures in most of the developed economies, future deployment of renewables could become more costly and less scalable because of their impact on electricity prices. Paradoxically, a too successful renewables policy could reduce the efficiency and effectiveness of future such policies.

In this paper, we ask to what extent concurrent policies of market liberalization and promotion of renewable technologies are compatible. Based on deduction reasoning we develop a general framework that permits us to theorize this relationship. Based on this approach, pursuing both policies are shown to be ultimately incompatible, regardless of the country, location, or type renewable technologies. This holds as long as the market clears with prices equal to short term marginal costs, and the renewable technology's marginal cost is close to zero, and is not dispatchable. This initial premise and resulting axiom are internally consistent and complete, which are postulated here as a foundation for future reasoning and empirical testing for different countries, market designs, and technological innovations.

Our postulate starts with the observation that current liberalized market mechanisms are based on two assumptions: positive marginal costs and the dispatchability of power (see for example [29,17]). Neither of these assumptions is applicable to renewable technologies -or at least to the most relevant ones: wind and solar- as they are largely intermittent, nonprogrammable and have almost zero marginal costs. These two characteristics explain why high market penetration of renewables leads to depressed and more volatile electricity prices.

In this scenario, renewables incentives become more expensive and lead to less deployment. Note that RES policy is setting progressively higher and higher targets. In 2008, the EU issued the 2020 Climate and Energy Package issued with a target of 20% of RES in 2020 [10] and more recently issued the 2030 Climate and Energy Policies Framework [11] with a target of 27% in 2030. In the US, NREL forecasts a target of 50% in 2050 [16].

Futuristic projections already envision the attainment of 100% RES share [13]. But based on existing market designs, 100 percent renewables penetration cannot be achieved because developers of renewable generation would be unable to earn a return on their investment without conventional technologies to provide a floor for electricity prices.

Our study suggests a potential theoretical and practical explanation for this puzzle:

- This paradox applies only to liberalized markets and not to centrally planned systems.
- Penetration of renewables capacity in the current configuration of liberalized markets has limits.

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- We focus on those renewable technologies that have the technological feature of having almost zero marginal costs and that have proven to be the most scalable types of technologies, wind and solar. If future developments allow to reduce these two technological features, zero marginal cost and intermittency, then the paradox may not hold.

Ignoring these findings can slow adoption and increase the costs of deploying new renewable technologies.

The rest of the paper is organized as follows: section two has a brief description of the functioning of liberalized electricity markets and the impact of renewable technologies on price formation. Section three explains why renewable technologies are difficult to integrate in liberalized markets. Section four explains the implications for renewable polices derived from the difficult integration of renewable technologies in liberalized markets. Section five explains the renewable energy policy paradox and explores the implications of the paradox. Section six presents our conclusions.

2. Electricity price formation in liberalized markets

Current liberalized electricity markets are the result of pro-market reforms that took place in the 1980s and 1990s to increase the competitiveness of the sector. Before the electricity system was previously organized as vertically integrated companies, as natural monopolies, and in most cases these were in public hands [20]. Liberalized spot electricity markets are designed using a marginalist approach. Existing power market designs operate on the assumption that electricity generation has a range of positive marginal costs that increase through some rank ordering, as is the case for thermal generators, based on technologies and fuel sources. This design is based on the construction of an efficient merit order through an implicit auction in the day-ahead market.

The market clearing price is set at the marginal cost of production of the last unit sold, which is the most expensive. In practice, power generators offer different quantities of electricity at various prices, which are ranked from cheapest to most expensive. Then, and for a given demand, the cheapest power plants supply electricity while the more expensive ones do not operate. Plants with marginal production costs that are lower than the market clearing price will be able to earn incremental revenues, which contribute to their fixed costs. The marginal plant will only be able to cover its variable operating and maintenance cost.

But this market design, when combined with the deployment of renewable technologies on a massive scale, is leading to a decline in wholesale electricity prices and an increase in price volatility, in particular in Europe. For example, Browne et al. [6] say that increasing wind penetration reduces spot market electricity prices due to the merit order effect in the short term. Clò et al. [7] conclude that solar deployment in Italy over the period 2005–2013 reduced wholesale electricity prices and amplified their volatility. De Vos [8] states that negative electricity prices result from a market distortion caused by renewable support mechanisms. Würzburg et al. [34] explore the impact renewable deployment in electricity prices in Germany and Austria. Paraschiv et al. [30] find that the deployment of renewable energies lead to extreme changes in electricity prices in the case of Germany. Dillig et al. [9] state that electricity prices in Germany, and also in Europe, dropped due to an excess of renewable energy. Azofra et al. [1] and Ballester and Furió [2] find that the renewable generation tend to decrease the price and tend to increase its volatility in the Spanish electricity market.

Fig. 1 explains the theoretical impact of renewable with a text-book model of electricity market. This figure shows that new renewable facilities "shifts" the supply curve, which in turn decreases prices. Given the intermittence of these technologies, the supply curve will increase and decrease depending upon climatologic conditions, which increases further the inherently –as large scale storage is not yet available- volatile electricity markets. The more penetration of renewables the larger the shift in the supply curve and the larger the price volatility.

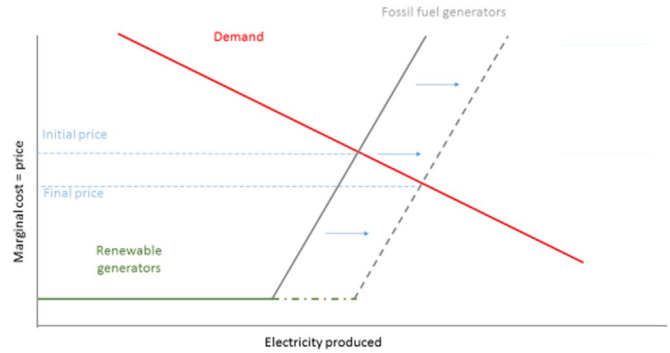

Fig. 1. Impact of renewable technology in liberalized electricity market.

However, this price drop does not reflect a true decline in the full cycle cost of producing electricity, though, but reflects the very low marginal cost of dispatch for renewables. This was not necessarily a problem in the context of vertically integrated utilities as they were more able to incorporate intermittent zero marginal cost output by distributing the costs within their overall rate structure. A liberalized market, on the other hand, makes this cost more transparent.

At the early stages of renewables deployment it was difficult to price the risk of these new untested technologies. Subsequently, more mature renewables entered the liberalized market and started to compete at almost zero marginal cost, with a relatively small and well-assessed risk, which investors found attractive. The rise of penetration of renewable technologies have been massive in recent years. According to the International Energy Agency [18], renewable deployment exceeded those of fossil fuels and nuclear for the first time in 2015. Currently, the world's renewable technology generation capacity at around 1 985 GW exceeds that of coal. The paradox is that Renewables' success could also lead them to their downfall.

3. An analysis of the Paradox from the market side perspective

The paradox is that the same market design and renewables policies that led to current success become increasingly less successful in the future as the share of renewables in the energy mix grows. The renewable energy policy paradox results from the interaction between several factors, including:

- the (almost) zero marginal costs of renewables
- the intermittent nature of renewables
- the interplay between price volatility and renewable technologies.

The first feature above explains why renewables have priority of dispatch.[1] The structure of renewable technologies, which have a high levelized cost of electricity but almost zero marginal cost of production, gives renewable energy priority in the order of dispatch. However, renewable technologies are often not the cheapest in terms of total cost, not marginal cost.

This leads to a divergence between the true cost of the system and the evolution of price of electricity in wholesale markets, in markets with high penetration of renewable energy. To illustrate this point, we performed simple calculations for three European countries using Eurostat[2] data which show a sharp decrease in wholesale prices that

[1] One could argue that low marginal cost generation is nothing new in competitive whole sale markets. This is true and in fact is a key characteristic of baseload technology. But our argument is that it the combination of both, low marginal cost and intermittency, what makes this case different.

[2] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en.

concur with high penetration of renewable capacity but also a surge in the final consumer price for the period 2008–2014. In Germany there was a simultaneous increase in the price of electricity to consumers of 41 percent, a decrease of the wholesale price of electricity of 50 percent and renewable penetration increased from 15.1 percent to 28.2 percent. In Italy, the price of electricity to consumers increased by 15 percent, the wholesale price of electricity decreased by 40 percent and, finally, renewable penetration increased from 16.6 percent to 33.4 percent. In the case of Spain, we observe an increase in the price to consumers of 62 percent, a decrease of the wholesale price of electricity of 34% and an increase in renewable penetration, from 23.7 percent to 37.8 percent. These stylized facts from some European countries suggest that renewable energy is leading to a divergence between the cost of the system and the price of electricity in wholesale markets, although these are not a proof of statistical causality.

There is an interesting interplay between price volatility and renewables penetration. As we mentioned earlier, price volatility is an inherent characteristic in electricity markets due to the lack of reliable and meaningful storage. Thus the presence of any non dispatchable generator would force conventional thermal power producers to make sudden adjustments to their production which leads to sharp changes in electricity prices. What we argue though is that this volatility is now compounded by the presence of unpredictable and intermittent technology. Increasing volatility due to RES penetration has been reviewed recently by Winkler et al. [32].

Depressed and more volatile electricity prices arising from high penetration of renewables are not ingredients for long term growth of these new technologies, unless costs are declining more quickly than the combination of market price drops and financing costs hikes.

Although this policy paradox is only now being recognized, the impact of renewable policies on markets has been widely discussed, with topics ranging from investor's behavior [27,32]; system flexibility, effects on prices, consumer choice and market institutional developments [14,23,25,26,28]. The conclusion of these studies is that distorted market signals endanger competition and the opaqueness of subsidy pass-through weakens consumer confidence. Whether the present market designs are appropriate in the transition to a low-carbon power sector has become a critical question.

4. An analysis of the Paradox from the policy side perspective

Policy objectives are criticized by some as "often inexplicit, unclear, not quantified and temporally unstable," [21]. For simplicity we assume that the objective of renewables policy is to deploy renewable capacity at the lowest cost possible as a proxy for reducing carbon emissions at the lowest cost. We acknowledge this is a restrictive assumption as, of course, there are alternatives, such as enhancing energy efficiency or other technologies including carbon capture and storage. For simplicity, let's also assume that there already exists a critical mass of renewable energy in place, this is, a mass of renewable that distorts the standard price formation in a liberalized wholesale electricity market. Accommodating a small quantity of renewables in the electricity system can be achieved without distorting prices, profits or incentives for investments.

The point is that considering renewables in isolation may prove to be self-defeating. In the new framework of liberalized markets, policymakers have three types of generic financial instruments to promote renewables:

1. Guarantee a fixed price for renewables production regardless of the market price. Examples include a feed-in tariff or a bilateral power purchase agreement.
2. Support renewables by paying a fixed amount on top of the market price, such as a feed-in premium or a production tax credit.
3. Provide a direct subsidy for initial investment like an investment tax credit or accelerated depreciation schedules.
4. A mandate to increase electricity production from renewable sources, like the Renewable Portfolio Standard. This policy, for this study, similar to a bilateral agreement between the utility and the renewable generator.

Our contention is that when these instruments are implemented in the markets with decreasing, but more volatile, prices – as is the case in electricity markets with high penetration of renewable technologies – the outcome will be either less deployment than expected initially, or more expensive policy support [4].

Investing in new renewables capacity is less attractive at a time of lower electricity prices, as they reduce expected profits as suggested by Gross et al. [15]. Also, private investors will likely demand higher rates of return as volatility raises the uncertainties over the projects. Lower expected profits and higher profit requirements inevitably reduce the number of projects commissioned in the absence of additional policy support. The level of a feed-in premium, for example, or of an investment credit, would need to be higher than otherwise in order to maintain a given level of investment.

Feed-in tariffs or bilateral agreements could be a potential way to manage this impact, since both guarantee a stable flow of revenues by fixing price, as it is suggested by Bürer and Wüstenhagen [5]. However, such instruments would lead to increasing levels of support as wholesale prices decline due to the penetration of new renewables capacity. Guarantors of the payments – either taxpayers through government, or consumers through surcharges on their bills – would need to compensate generators better to cover the difference between fixed and spot prices in these liberalized markets. In the short term, consumers may benefit from the decline in electricity prices, while the equity value of incumbent generators may deteriorate (see, for example, Financial Times [12] for anecdotal evidence).

In the longer term, investors will not reinvest or recapitalize electricity markets without sufficient guarantees on returns. These additional costs will eventually be borne by taxpayers or consumers. In Germany the feed-in tariff subsidy program has already cost more than $468 billion, and its total cost could exceed $1.3 trillion by the time it expires, according to 2015 estimates. German consumers paid an 18 percent surcharge on their monthly power bills in 2014 to finance renewables. This is more than a fivefold increase since 2009 [22]. In the US, the total direct federal financial interventions and subsidies in energy markets decreased from $38.0 billion in 2010 to $29.3 billion dollars in 2013, reflecting policy changes.

5. Implications of the renewable energy policy Paradox

Full decarbonization of a power sector that relies on renewable technologies alone, given the current design of these markets, is not possible as conventional technologies provide important price signals. Markets would collapse if the last unit of fossil fuel technologies was phased out. In the extreme (theoretical) case of 100 percent renewables, prices would be at the renewables marginal cost, equal to zero or even negative for long periods. These prices would not be capturing the system's costs nor would they be useful to signal operation and investment decisions. The result would be a purely administered subsidy, i.e., a non-market outcome. This is already occurring in Germany as Praktiknjo and Erdmann [31] point out and is clearly an unstable outcome. Thus, non-dispatchable technologies need to coexist with fossil fuel technologies.

This outcome makes it impossible for renewables policy to reach success, defined as achieving a specified level of deployment at the lowest possible cost. With volatile, low and even negative electricity prices, investors would be discouraged from entering the market and they would require more incentives to continue to operate.

Important is to notice the presence of a 'renewables blend wall'. We use this term to refer to the point when sufficient renewables penetration materially reduces the market clearing price, or marginal cost of the most expensive facility required to meet demand, below the full cycle cost of new baseload generation. This would be a violation of the microeconomic principle where profit maximization is attained when price equal to marginal cost (maximum condition) and the price is greater than average cost (break-even condition). Until this point the costs of integration are largely operational and of limited consequence to the overall price of delivered power. Beyond this point, the failure of the liberalized market structure to provide market players with a return on their investments requires the introduction of more costly adjustments. These can include capacity payments, investment support and even mandates to maintain plants that would otherwise be mothballed or decommissioned. By recognizing the presence of this “blend wall”, we should ask whether there a risk of over investment in renewables, beyond the optimal level for societal welfare.

Alternative price setting mechanisms have been tried in liberalized electricity markets. One, known as a pay-as-bid auction, is where each market generator receives its actual bid, again up to the highest market clearing bid. However, pay-as-bid auctions are not the standard way to organize liberalized markets since they promote strategic bidding, often not reflecting marginal costs. The reason is that generators behave strategically in order to make a profit maximizing competitive bid, avoiding rejection [19,24,33]. In addition, pay-as-bid can lead to inefficient dispatching as lower or less aggressive bids from more costly plants are accepted. The liberalization of U.K. power markets in the 1990s used a variant of pay-as-bid where all bidders received the clearing price. This was also dropped, for the same reasons.

Subsidization does not help to solve this paradox, because given their technological characteristics, their marginal cost is already zero. Then, it is possible to have at the same time lower costs of renewable technologies and insufficient revenues from electricity markets to cover those costs.

6. Conclusion

This paper pinpoints the renewable energy policy paradox and explores the need for a rethink of the foundations of market liberalization, given that current power market designs cannot satisfactorily accommodate renewable policy mandates without distorting electricity prices.

There are some important implications of this finding, pertaining to the issue of inefficiency and lack of transparency in the market outcome. The first implication is that this paradox applies only to liberalized markets and not to centralized systems. Liberalization has been advocated and implemented precisely with the aim to increase efficiency, avoiding the monopolist distortion and letting market competition to rule and to increase transparency, disposing of the opaque cross-subsidization mechanism implicit in the management of the vertically integrated monopolist. In this sense, a competitive renewable-dominated electricity market cannot deliver an efficient outcome is the root problem. This is a crucial issue for policy development in those countries where the liberalization of the power sector has not been fully implemented and there is a policy strive to increase the share of renewables.

The second is that renewable penetration, in liberalized markets, has a limit. There is a cap to the capability of the decentralized market to deliver with transparency the proper market signals. Thus we argue that full decarbonization of the power sector is not attainable. Without conventional technologies, or a mechanism that captures proper price signals from renewable, prices would be zero or negative. Ironically, conventional technologies play a key role in renewable deployment, and as a consequence, indirectly, in decarbonization.

There are three potential responses to the issues presented in this study. The first is to go back to a centralized market. In this case, a cost-benefit analysis is needed to determine whether the potential benefit of the easy integration of renewable technology offsets the cost associated to noncompetitive markets. The second is to redesign the market clearing mechanisms to accommodate renewable energy. Bigerna and Bollino [3] present a new market design, but additional research is needed to explore alternative reforms. The third approach is to subsidize fossil fuel generators, through capacity payments for example, or to reverse penetration of intermittent, zero marginal cost renewables. The former would imply the end of the market as all the participants –fossil fuel and renewable generators- would be subsidized, emerging the question on the practical relevance of the electricity market. For the latter, it is not really an option due to climate change concerns.

New market mechanisms need to be designed, based on two main pillars. First, it is necessary to reform the market in order to capture the full renewable cost structure. Second, it is necessary to more accurately compensate conventional technologies. This is crucial to convey the correct market signal to new investors in both technologies: on the one side, renewable investors need to know the social value of renewable generation for environmental goals and, on the other side, conventional sources investors need to know the correct value of their contribution to security and reliability system management.

To summarize this paper has tried to unveil the incompatibility between electricity liberalization and renewable policy, regardless of the country, location or renewable technologies through induction and empirical observations. The Paradox holds as long as market clear prices with short term marginal costs, and renewable technology is close to zero marginal cost and it is intermittent.

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