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Comments on Richard Green's and Iain Staffell's "The Impact of Government Interventions on Investment in the GB Electricity Market"

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Summary

This study has been written by Emmanuel Frot, François Lévêque and Marcelo Saguan[1] at the request of EDF to provide an academic review of Richard Green's and Iain Staffell's "The Impact of Government Interventions in the GB Electricity Market"[2]. **The findings and conclusions expressed here are, however, solely those of the authors and do not necessarily represent the views of EDF.**

We acknowledge the quality of the work realized by Prof. Green and Dr. Staffell who chose to use a carefully constructed economic model in order to precisely quantify the impacts of diverse government interventions in the UK electricity market. We also highly regard their transparency about the data they used and the assumptions they made to predict future market trends as it allowed us to get a clear picture of their model from the report.

Richard Green's and Iain Staffell's report is used as an input by the European Commission in its notification to the United Kingdom of its decision to initiate a State Aid procedure regarding the investment contract for the Hinkley Point C new nuclear power station. The European Commission refers to the analysis in section 8.1.7 of its decision, where it discusses potential distortions of competition and trade. Paragraph 401 of the decision indicates that "*The Commission has asked Professor Richard Green and Dr Iain Staffell (…) to inform its assessment by providing a report (the 'Expert Opinion') on the likely impact of the notified measure on the competitive conditions of the UK electricity markets*".

The European Commission quotes the report to conclude that the 35-year Contract for Difference (CfD) proposed by the UK would decrease welfare compared to a scenario without government intervention and that the notified measure can have substantial distortive effects on competitive conditions.

Our review raises doubts about this conclusion on the basis of the Green and Staffell report. We duly acknowledge its relevance to illustrate the impact of various government interventions on installed capacities, to understand the timing of investment in the various technologies and to provide an informative assessment of price levels under different scenarios. On the other hand, we claim the GS methodology is not appropriate to balance the economic merits of various measures on the electricity market and in particular to run a welfare analysis or a distortion assessment. We substantiate this claim by clarifying a whole set of assumptions Green and Staffell make and that strongly conditions their findings. We show in particular that the economic model they use to make predictions artificially separate investment decisions from risk, on the basis of a restrictive assumption of risk neutrality. That modelling choice prevents the model from properly dealing with the existence of financial market failures, a common feature in energy markets.

This unfortunate simplification is combined to an assumption of exogeneity for the weighted cost of capital (WACC), a central parameter of the model. The authors choose its value without any proper justification in the various scenarios they consider. Some of their conclusions may be reversed if one adopted slightly different WACC values. In other words, the conclusion the European Commission emphasizes is actually not robust to a small change in GS assumptions.

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[2] http://ec.europa.eu/competition/state_aid/studies_reports/green_staffell_en.pdf

We additionally show that Green and Staffell neglect four other types of market failures that typically affect energy markets: learning externalities, market power, diversity of supply, and carbon externalities:

- The authors do take learning into account but make the assumption that learning is exogenously given, as if technical spillovers in the building of new nuclear plants were global and did not include any local dimension. That assumption has the advantage of cancelling any market failure due to learning but, in doing so, it precisely fails to consider a benefit of government intervention on technology deployment.

- The authors consider carbon emissions and measures to deal with carbon externalities in their model but they do not take them into account when assessing total welfare.

- The other two market failures are simply ignored by Green and Staffell. Their choice negatively biases their conclusions against government intervention. GS neglect for instance the procompetitive properties of CfD in presence of market power and the benefits of supply diversification. It does not recognize that the market is not efficient and that policies may alleviate its failures.

Putting together the different assumptions and modelling choices of Green and Staffell, we claim that their findings are valid in a world where WACCs do not necessarily reflect the level of risk of each type of investment, where economic agents are risk neutral, where learning effects are global such that there is no market failure due to learning externalities, and where markets are perfect enough to yield the socially optimal diversity of supply. The benefits of government intervention are underestimated because the market is implicitly assumed to be close to being perfect. In addition, comparisons between different types of intervention are flawed as their relative merits are ignored.

As a consequence, the validity of Green and Staffell’s conclusions on welfare and on the merits of government intervention in a realistic representation of the UK energy market is far from being warranted. Their findings are not robust to small changes in the assumptions and may actually be reversed if one acknowledges the impact of market failures on welfare.

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1 Introduction

This study proposes a review of Richard Green and Iain Staffell's "The Impact of Government Interventions in the GB Electricity Market" report, hereafter GS, which makes predictions about the evolution of the electricity market in Great Britain in the context of the European Commission investigation for State Aid Approval of the 35-year Contract for Difference (CfD) for the proposed nuclear power station at Hinkley Point C.

Their report is used as an input by the European Commission in its notification to the United Kingdom of its decision to initiate a State Aid procedure regarding the investment contract for the Hinkley Point C new nuclear power station. The European Commission refers to the analysis in section 8.1.7 of its decision, where it discusses potential distortions of competition and trade. Paragraph 401 of the decision indicates that "*The Commission has asked Professor Richard Green and Dr Iain Staffell (…) to inform its assessment by providing a report (the 'Expert Opinion') on the likely impact of the notified measure on the competitive conditions of the UK electricity markets*".

We would like first to acknowledge the quality of the work realized by Prof. Green and Dr. Staffell who chose to use a carefully constructed economic model in order to precisely quantify the impacts of diverse government interventions in the UK electricity market. We also highly regard their transparency about the data they used and the assumptions they made to predict future market trends as it allowed us to get a clear picture of their model from the report.

GS considers, alongside the 35-year CfD, alternative policies regarding the existence, the type, the scope and the duration of the measure. For each of these scenarios, it uses a model of the wholesale electricity market in Great Britain which generates investment decisions and electricity prices based on a set of exogenous parameters, including in particular the type of support granted to the Hinkley Point power station. The model delivers price and capacity trajectories that represent market fundamentals and rational investment decisions. It aims at constituting a useful guide to assess the impacts of various aid schemes.

While the approach adopted by GS is undoubtedly insightful, it relies on a set of assumptions that we feel could be more explicitly formulated (section 2). With these assumptions clarified, we can then move on to their impact on the conclusions put forward by GS. The key motivation with doing so is to help the reader understand the type of market where the GS conclusions hold in order to appreciate their external validity (section 3).

2 Some assumptions in GS require clarification

GS use a model composed of three interrelated modules that aim to represent the economic mechanisms of the GB electricity market.

A first module reflects the generators' decisions to invest. It generates a set of installed capacities for each type of energy, under the assumption that generators will stop investing when additional capacity would not break even over the course of its lifetime.

The dispatch module takes the outcome of the investment module in terms of capacities to compute the corresponding electricity prices and hence generators' profits, plant utilisation, and welfare. These of course depend on exogenous parameters: demand, fuel prices, installed capacities of renewables, market rules, etc. The investment and dispatch modules are interrelated as for a given set of installed capacities corresponds a different equilibrium in prices, profits, etc. which itself influences investment decisions. The model therefore loops over these two modules until it reaches an equilibrium where investment decisions lead to prices and profits consistent with these decisions. The modelling ensures that the outcome reflects a consistent economic equilibrium.

The third module relates to risk. It takes as given the installed capacity resulting from looping over the investment and dispatch modules and runs a sensitivity analysis by modifying various input variables, in particular fuel price forecasts.

Our point in this section is not to list all the assumptions the GS model relies on but rather to underline some key hypotheses that condition the results of the model in a potentially significant manner. Any model must make simplifying assumptions to focus on its key ingredients and this approach is to be praised. On the other hand, one must make these assumptions very clear to let the reader appreciate their validity, and this is what we are striving for in the following paragraphs.

A second objective of this section is to underline a few points that, in our opinion, should be clarified. These concern the reasons of debatable choices of parameters or assumptions we could not precisely identify.

2.1 Interaction between the three modules

The model, as presented on page 8 of GS, consists of two loops. The first combines the investment and dispatch modules. It yields installed capacities, prices and profits in equilibrium and constitutes the core of the model. The second combines the risk and dispatch modules. It comes second in modelling the electricity market as it takes the outcome of the first loop as given. This is apparent on page 8 where GS state that "*once the optimal set of decisions for the whole period (2010 to 2100) has been found, the model loops between the risks and dispatch modules*", but also on page 21 where it is explained that "*for [the market with no intervention and the UK government's proposed CfD], we ran the model with the central fuel prices to fix the capacity of each type of power station. We then allowed the fuel prices to vary and recorded the profits made by each type of plant that might be built in the 2020s to the 2030s."* Section A.3 similarly describes the method to take investment risk into account: "*Once a sequence of investment decisions and capacity levels has been obtained, we simulate the risks faced by generators, running the model for a variety of different short-term fuel prices without changing the capacity mix."*

This model representation is slightly misleading for two reasons. First, while the two loops are indeed executed, they are in a subsequent fashion and not simultaneously. One would expect that when running the sensitivity analysis to fuel prices, the results of the dispatch module interacting with risk module would feed into the investment module. This is not the case and *the installed capacity is* *never affected by varying fuel prices*. In other words, investment decisions solely rely on the central fuel prices, demand, and renewables scenarios. This assumption has significant consequences in the model, as will be made clear later.

Second, the figure on page 8 and the text in the last paragraph on the same page include a feedback loop that is actually ignored in the model. GS write that "*The risk module assesses the resulting variation in profits, and thus the robustness of the investment decision. Ultimately, this can be used to alter the discount rates applied to each technology and vintage by factoring the variance in profit into the technology's risk premium, which can then be fed back into the first loop.*" It can indeed be done, but it is not part of the GS report, such that the arrow going up from the risk module to the investment module through discount rates is shut down. This is not an innocuous assumption as *it completely disconnects any measure of risk from the WACC generators use when making their investment decisions*. This is of course duly acknowledged by GS, for instance on page 9 where the cost of capital appears as an input of the model, and not as an endogenous variable like electricity prices and installed capacities. However the implications of this choice when comparing the different policies are not made clear.

The model, illustrated on page 8 is therefore more linear than it may seem at first sight. The outer loop from the risk to the investment module is inhibited and the risk-dispatch module does not interact with the investment module. **To sum up, the GS model makes two important assumptions about the general functioning of the electricity market. It first disconnects risk and investment by assessing the impact of variation in fuel prices while considering pre-determined installed capacities. Second, it disconnects risk and investment by shutting down the feedback loop from risk to cost of capital.**

These two assumptions are closely related to considerations about generators' attitudes to risk, which we develop next.

2.2 Attitudes to risk

GS do not formulate clear assumptions about how generators take risk into account when deciding about their investments. These can however be recovered indirectly. We established that the GS model disconnects the dispatch-investment loop from the dispatch-risk loop. Sections 3.5 and A.3 in GS make it very clear by explaining that the impact of risk is assessed *after* capacities have been derived from the dispatch-investment loop. Section 3.5 also indicates that these capacities correspond to the central fuel prices scenario, which we interpret as expected future prices at the time of the investment.

The disconnection between risk and investment decisions is economically equivalent to the risk neutrality of generators. This is fully consistent with the fact that the impact of risk can be measured by first deriving capacities and then by varying fuel prices in Monte Carlo simulations, as in section 3.5 of GS. Risk neutrality is implicitly assumed by GS as any deviation from this assumption would make the model inconsistent by preventing the disconnection between risk and investment. Without risk neutrality, the Monte Carlo simulations would not be consistent with the investment decisions taken as given and the model would break down from an economic viewpoint, though it would still be computationally feasible.

Assuming risk neutrality is not standard in the economic literature on electricity markets[3] and GS do not provide the motivations for their choice. Given that the way economic agents consider the risks

[3] See, among others, Bessembinder and Lemmon (2002), Defeuilley and Meunier (2006), and Meunier (2013).

associated to various technologies would be expected to play a key role in determining the equilibrium, it is somewhat surprising that the assumption is neither discussed nor, at the very least, explicitly formulated.

GS assume that generators are risk-neutral, considering only the expected returns associated to each technology but not their variance.

2.3 WACC

The WACC is a key parameter of the model and GS accordingly run several sensitivity analyses varying its value. GS make it clear that the WACC for each technology and each type of contract is exogenously given such that it is an input of the model and not an endogenous outcome (see section 2.2 in GS). From an economic point of view though, the WACC results from the interaction of economic agents assessing the risks characterizing each technology. It is an equilibrium outcome and not an exogenous parameter.

GS, by disconnecting the risk and investment modules in the model, allow the WACC to be exogenously imposed. A key consequence is that the WACC in each scenario does not necessarily correspond to its equilibrium value. For instance on page 4, the No aid scenario has a WACC of 13%, the CfD35 scenario a WACC of 10%, and the FiP35 scenario a WACC of 10%. The relativity between these values of WACC is arbitrary in the model. It may be that, faced with the FiP35, investors would ask for a WACC higher than 10%. It could also be that the equilibrium WACCs in the CfD35 and FiP35 scenarios would not be the same. The model does not shed any light on this point.

GS assume that the WACC is exogenously given and does not originate from the interaction of the risk and investment modules.

This assumption has direct consequences when interpreting the results of the GS model. In particular, it isolates the model from any consideration on risk and how it feeds into investment via the cost of capital.

2.4 Learning-by-doing

GS assume that total capital costs fall over time, as shown on the figure page 30. A key feature of this graph is that costs decrease over time and not over cumulative installed capacity. According to this assumption, the costs of building a first EPR in the 2040s or of building a second, third, or even tenth EPR in the 2040s are the same. This is the case if learning takes place at the global level and if installed capacities abroad are exogenously given. While the latter may be approximately correct, or at least a reasonable assumption in a model, the former requires some justification, unfortunately absent from GS.

Global technological spillovers do exist and the UK may at least to some extent benefit from the experience acquired by, say, China in building EPRs. However national spillovers also play a role and assuming them away is a strong assumption. The supply chain to build nuclear power stations is partly localized. Local engineers and workers learn how to manage the relationship with the national safety authority (framework and modeling for technical evidence, requirements implementation…), to build the plants and to produce their components more efficiently with each plant they build and component they produce. The hypothesis of local spillovers is systematically chosen by experts on the topic and well documented[4]. In the context of the GS study, it significantly affects the results and should be kept in mind when reading the conclusions of the report.

GS assume that learning takes place at the global level and disregard any national spillovers that would make the total capital costs of each technology decrease with its installed capacity.

2.5 Market power

Section A.4 in GS indicates that energy markets are perfectly competitive. This textbook assumption may be innocuous as long as it does not affect the conclusions of their model. A key question, examined later, is whether different policy instruments have different properties in terms of procompetitive effects on the electricity market.

GS assume that energy markets are perfectly competitive.

2.6 Security of supply

Security of energy supply is a key feature of electricity markets from a social standpoint. It is desirable for a country to rely on diversified sources in order to hedge against the risks of a sudden increase in fuel prices or geopolitical risks. However market forces may fail in delivering the optimal fuel mix from a macroeconomic point of view and government intervention may help in tipping the market in a welfare improving direction. The GS model does not take into account the desirability of a diversified fuel mix and therefore does not integrate the benefits of any diversification.

GS assume diversity of supply is not welfare improving.

2.7 Carbon emissions

GS introduce a carbon price in their model such that generators decide about installed capacities taking carbon externalities into account.

They then compute total carbon emissions in each scenario but exclude them from welfare definition. This may seem odd when one's objective is to assess the relevance of a support scheme with the explicit purpose of reducing carbon emissions.

GS assume lower carbon emissions are not welfare improving.

[4] See for instance : Zimmerman M. B., "Learning effects and the commercialization of new technologies: The case of nuclear power", *The Bell Journal of Economics*, 13, 297-310, 1988; Cantor R. and Hewlett J., "The Economics of nuclear power: Further evidence on learning, economies of scale and regulatory effects", *Ressources and Energy*, 10(4), 315-335, December 1988; NEA/OECD, *Reduction of capital costs of nuclear power plants*, 2000; and G.S. Tolley, *The Economic Future of Nuclear Power*, A Study conducted at the University of Chicago, August 2004.

3 GS conclusions are biased against government intervention in terms of welfare assessment

The preceding section clarified the assumptions the GS model relies on. We showed in particular that it adopts a framework with risk neutrality, the absence of market power, a very specific type of technological learning-by-doing, the absence of security of supply issues, and of the benefits of lower carbon emissions.

This section brings together these preliminary findings to estimate the external validity of the conclusions derived from the GS model. It combines the assumptions of the model with some key economic features of energy markets to identify the areas where the model brings insights and those where it cannot address the issues at stake.

Our comments are split in two subsections. First, we argue the assumption of an exogenous WACC is critical and restrict the validity of the GS report to a very specific economic world, an unknown one indeed. Second, energy markets are characterized by a set of market failures that government interventions aim to cope with and we examine how the GS model allows one to conclude about the relevance of these interventions.

3.1 Exogeneity of the WACC is a critical assumption

The WACC in the GS model is a critical parameter that conditions many of its conclusions. Despite being central, it is disconnected from any economic mechanism and its values do not necessarily correspond to an economic equilibrium. *This modelling choice could be considered as a useful simplification that makes the model more tractable, at little cost for its realism. Our claim is the opposite.*

As an illustration, consider the transition from the No aid scenario to the CfD35 scenario in GS. It results, by assumption, in a 3 point WACC decrease. This cost reduction is just enough to trigger investment in nuclear capacities in the 2020s (see pages 44 to 46 and section 3.5.3). The FiP35 scenario is assumed to have the same WACC than the CfD35. GS then make comparisons between these two scenarios and the No aid scenario, claiming that a Feed-in-Premium delivers new nuclear plants in the 2020s, albeit at a lower level than the CfD policies and that a CfD35 reduces welfare compared to the market without intervention.

These conclusions are correctly derived from the model but they all rely on a WACC value that may not reflect the market fundamentals of each scenario. As is clear from Annex C in GS, the value of the WACC greatly impacts welfare and any change in its assumed value may reverse GS conclusions. The issue in the GS model is that it cannot inform us about which assumptions are correct, despite their criticality.

For instance, the CfD35 and FiP35 scenarios both result in new nuclear plants but the CfD35 entails a lower welfare (£36.2 vs. £37.3 billion with a 10% WACC). However GS do not prove that both scenarios would result in the same WACC. As we argue below, on the basis of GS own results, it is actually likely that the WACC would be higher with a FiP35 and this may reverse GS conclusions.

The main findings in GS critically depend on exogenous WACC values that do not necessarily correspond to an economic equilibrium. Their conclusions on welfare could be reversed with slightly different assumptions about WACC values, in particular in the CfD35 and FiP35 scenarios.

3.2 Market failures

Energy markets are usually considered in the economic literature to be characterized by different types of market failures that justify government intervention.

GS start by exploring in section 3.1 the market outcome in the absence of any government intervention. This canonical step is critical in economic assessment because it sets a benchmark against which intervention can be evaluated by comparing how policy instruments may alleviate existing market failures that make the market outcome inefficient. The net present value of welfare subsumes this idea: a higher welfare in a scenario with market intervention must somehow compensate the detrimental effects of some market failures.

The issue in GS is that market failures are not identified. The conclusions of their model cannot be interpreted in terms of State Aid assessment regarding welfare and distortions without having first specified the market failures that the aid scheme addresses and having detailed how the model takes them into account.

We address this issue in the following sections and argue that the GS model fails to acknowledge different key market failures. Five are discussed: financial market failures, learning externalities, market power, diversity of supply, and carbon emissions. We show that the first is taken into account by GS, but unsatisfactorily, while the others are ignored.

3.2.1 Financial market failure

Government intervention can solve some market failure on financial markets that lead to an underprovision of funds to infrastructure projects. GS do not specifically mention the existence of such a failure but take it into account through the WACC value. Its reduction from 13% in the No aid scenario to 10% in the CfD35 and FiP35 scenarios may reflect the fact that financial markets require too high a cost of capital compared to its optimal value.

This is the case if, for instance, financial markets are incomplete such that risk-averse agents are not offered the possibility to hedge the risks stemming from investing on energy markets. In order to contribute to the debate about the best policy to solve this market failure, one has consequently to formulate assumptions about the way attitudes to risk shape market outcomes. It is on this particular point that GS fails.

We showed earlier that GS implicitly assume in their model that economic agents are risk neutral. This allows GS to isolate the risk module from the investment module and to run a sensitivity analysis taking installed capacities as given.

This assumption generates contradictions in the GS report. First, section 3.5 carries little value when generators are risk neutral. It merely describes profits distributions that have no effects whatsoever on investment decisions. This is a peculiar feature of the model that may be justified when one is not interested in studying risk, but is inconsistent with a section on the topic.

Second, GS fails to acknowledge that *the different revenue dispersions are expected to result in different WACCs* absent risk neutrality. For instance in the CfD35 scenario (section 3.5.3), the corresponding WACC is 10%. In the FiP35 scenario (section 3.5.4), revenues are more uncertain as the contract does not hedge generators from fuel price uncertainty but the WACC is still 10%. This result is unlikely to hold in reality and misses a key feature of the CfD, namely that it offers a better hedge than the FiP and is therefore potentially better suited to address a financial market failure. The GS model cannot capture this effect as the WACC is exogenously given.

GS adopt a somewhat inconsistent view on financial market failures. They implicitly recognize their existence by having the WACC depend on the type of government intervention. At the same time, a risk neutrality assumption is implicitly made. But risk neutrality ultimately strips sensitivity analyses of their interest and annihilates the relationship between risk and investment that plays a key role in the financial market failure. This approach, half recognizing and half ignoring the market failure, is incomplete and **prevents the model from drawing realistic conclusions for markets where financial market failures play any role.**

3.2.2 Learning-by-doing

Technological learning creates a positive externality that makes the market equilibrium suboptimal without government intervention as generators may be unwilling to be the first to invest in a costly technology, without realising that this investment will benefit the whole society by lowering the costs to produce new units in the future. This type of market failure can be addressed through government intervention, for instance by supporting a technology with a steep learning curve in order to accelerate its adoption.

GS assume the existence of a learning curve but, as established above, it describes global and not nation-wide learning. As GS exclude any local learning-by-doing, there is consequently no externality and hence no market failure due to technological learning in their model. Government intervention is bound to distort an efficient market from the point of view of learning.

More importantly, the existence of market failure due to learning effects will alter the way government intervention is assessed. In the CfD35 scenario, the government effectively supports the nuclear technology which, in the case of learning externalities, would alleviate a market failure. Early investment would confer some advantage to the CfD35, and raise welfare. The GS assumption of exogenously decreasing costs on the contrary penalizes the CfD35 scenario compared to the FiP35 scenario. Generators invest later in nuclear capacities with a premium than with a CfD but, as costs exogenously fall with time, this lowers the cost of a FiP policy compared to a CfD. There is an inherent, but flawed, advantage to government interventions that delay investments in nuclear capacities in the GS model.

That effect should be at least partly compensated by a benefit from being an early adopter and from speeding up the fall in costs. Taking the learning externality into account would penalize the FiP policy as it would result in later adoption than predicted by GS, hence shift it further from the social optimum. **The GS model is unfavourably biased against the CfD scenarios because of its failure to take into account nationwide, positive learning externalities.**

3.2.3 Market power

GS assume that markets are perfectly competitive. By construction, the No aid scenario is therefore free from any market failure related to market power. From this point of view, government intervention is useless and only introduces competition distortions on an otherwise efficient market.

This choice fails to account for an advantage of CfD identified in the economics literature, reviewed in the Appendix of this document. CfD has a procompetitive impact on the power market as it reduces the incentives of generators to increase prices on this market. This benefit does not exist with a FiP contract since it does not disconnect generators' profits from power prices. This property of CfD is expected to increase welfare in the CfD35 scenario relatively to welfare in both the No Aid and the FiP35 scenarios. Unfortunately, the GS model assumes away any market power and does not offer any insight on this point.

GS claim on page 7 of their report that "*[in presence of market power], prices would be higher in all the cases [they present]*" and somehow use this argument to justify that the risk for the exercising of market power at the detriment of consumers would be equivalent in all configurations. This is wrong. In the case of **imperfections in the power market, the CfD will result in a relatively higher welfare level than the No aid or Feed-in-Premium scenarios.**

3.2.4 Diversity of supply

Diversity of supply offers an insurance against the large price increases of a single source of energy. It is, in this sense, a public good for the society. But, as for any public good, a decentralized market is unlikely to provide its optimal quantity. Roque, Newbery and Nuttall (2008) put it very clearly: "*Electricity markets may not appropriately signal for the need of diversity and flexibility at the macroeconomic level. (…) A perfect market should motivate individual investment decisions leading to the socially optimal fuel mix, but the conditions for this to hold are strong – the usual General Equilibrium assumptions of a complete set of spot and forward markets or perfect foresight, price-taking behaviour by producers and consumers, risk neutrality (or adequate risk-sharing contracts), and convex production possibilities (Arrow and Debreu, 1954, Debreu, 1959). The lack of informative distant futures markets may lead to a suboptimal degree of diversity. (…) Moreover, imperfections in capital markets may limit the ability of utilities to diversify their risk exposure*." The market failure leading to suboptimal diversity calls for government intervention in order to achieve "*the macroeconomic and security of supply benefits of a diverse fuel-mix.*"

GS overlook any benefit related to diversity of supply. A single source could, potentially, do equally well than a diversified mix in their model. They implicitly assume that investment decisions are efficient thanks to a perfectly functioning market but, as Roque, Newbury and Nuttall argue, "*this is wildly unrealistic*".

Acknowledging the importance of diversity of supply and the failure of the market to deliver its optimal level is likely to reverse the conclusions of GS. The CfD35 scenario leads to a lower welfare than the No aid scenario according to their report. This ignores a key advantage of the CfD35 scenario over the market outcome: by triggering investment in nuclear capacities in the 2020s, it ensures that the UK benefits early on from a diversified fuel mix whereas the absence of nuclear plants after the 2030s in the No Aid scenario decreases the security of supply. It is therefore not surprising that **welfare in the CfD35 scenario is lower than in the No Aid scenario as the analysis ignores a key economic benefit of the CfD35.**

3.2.5 Carbon emissions

Carbon emissions represent a typical example of negative externalities that markets fail to correctly address. Because emissions are not valued at their optimal level, the private marginal cost of adding more carbon in the atmosphere is lower than the social cost. That results in welfare decreasing emissions. Different tools can be used by governments to implement the socially optimal level of emissions: these include taxes, setting an emission permit market, supporting technologies with lower emission levels, etc.

GS model is well suited to measure the impact of various measures on carbon emissions as it predicts the installed capacities from different technologies. A CfD35 for instance results in the lowest cumulative carbon emissions on page 4 of GS, while the market without intervention generates the highest level.

This observation should positively affect the welfare under a CfD35 and negatively affect welfare in the No aid scenario. This is not so. Whereas emission levels are known, GS fall short of integrating these values into the calculation of welfare.

Their approach regarding welfare emissions is in essence identical to the one adopted for other market failures. The market without intervention is implicitly assumed to be perfect and the reduction of emissions cannot bring any benefit. This is in contradiction with the objective of lower carbon emissions embedded in the CfD35.

Welfare in the CfD35 scenario would be relatively higher compared to welfare in the No aid scenario if carbon emissions had an effect on welfare.

3.2.6 Conclusions

Five types of market failures were addressed. They all are common features of electricity markets and are widely studied in the economics literature. **The GS model either ignores or does not deal properly with market failures. As a consequence, its conclusions are negatively biased against government intervention in terms of welfare assessment and minimize the benefits it could bring by solving some market failures.**

4 Conclusions

GS offer a set of insights relying on a dynamically consistent model of investment, wholesale prices and profits. Their opinion provides key results on market dynamics, nuclear technology adoption, prices, and carbon emissions. As has been shown, its results rely on specific assumptions that must be kept in mind when assessing the external validity of the model. We claim in particular that the model is not designed to run a welfare analysis or to assess the importance of distortions.

Its conclusions apply to a world where WACCs do not necessarily reflect the level of risk of each type of investment, where economic agents are risk neutral, where learning effects are global, where energy markets are perfectly competitive, and more generally where markets are perfect enough to yield the socially optimal diversity of supply.

We demonstrated that these assumptions are not mere simplifications that allow the model to be tractable but have significant consequences in terms of the costs and benefits of the various government interventions considered in GS. Their benefits are underestimated because the market is implicitly assumed to be close to being perfect. In addition, comparisons between them are flawed as their relative merits are ignored. The GS model is overall negatively biased against government intervention, especially against the CfD instrument.

As a consequence, the validity of Green and Staffell's conclusions on welfare and on the merits of government intervention in a realistic representation of the UK energy market is far from being warranted. Their findings are not robust to small changes in the assumptions and may actually be reversed if one acknowledges the impact of market failures on welfare.

5 Appendix: CfD and market power

5.1 Why is the "contract for difference" procompetitive?

It is well known that existing forward contracts mitigate market power. The basic intuition for this property is simple. A forward contract reduces the residual demand faced by a generator in a power market. As the residual demand is reduced, the generator has fewer incentives to exert market power and increase its price. The "contract for difference" proposed for the Hinkley Point C (HPC) plant has an impact on power markets similar to standard forward contracts. Thus the related economic literature can be used to shed some light on the properties of this instrument.

The contract for difference is for a particular quantity Q at a strike price R. R is the regulated price to be used to define the amount to pay the generator after the power market price p is determined, i.e. $(R-p)Q$. If the power market price ends up being higher than the strike price $(p > R)$ then the retailer will receive money from the generator, and the other way around. Incentives to increase the price in the power market can be analysed comparing two cases: one without a contract for difference and one with a contract for difference:

- Profit of the generator without contract = $(p-c)\ Q$
- Profit of the generator with a contract for difference = $(R-p)\ Q + (p-c)Q = (R-c)\ Q$

where c is the cost of producing one unit and assuming that the quantity of the contract for difference is equal to the quantity sold in the power market (Q).

In the first case the generator has an incentive to increase the price because his profits depend directly on p, the price in the power market. Withholding some capacity (reducing Q) will increase the price and, potentially, profits as long as the demand is inelastic. In the second case, on the contrary, the generator has no incentive to increase the power price given that his profits are independent of p[5]. Similarly, any reduction in capacity decreases profits. Overall, the incentives to exert market power disappear with a contract for difference whereas they are fully present in its absence.

In what follows, we briefly describe some important insights from the economic literature (theoretical and empirical works). This literature clearly concludes that existing and/or regulated forward contracts have a pro-competitive effect in the power market.

5.2 Theoretical work

Many authors have studied theoretically the above intuition (see for instance, Allaz and Vila 1993, Newbery 1998, Green 1999, Stoft 2002, Willems 2006, Bushnell 2007). This theoretical literature considers the interaction between two sequential markets: a forward contract market and a spot market. Allaz and Vila (1993) can be considered as the starting point of a long-lasting discussion about how forward contract limits the ability of players to exercise market power.

This strand of literature generally starts by analysing the impact of the existing forward contracts on the spot market and concludes that forward contracting has pro-competitive effects on the spot market (Anderson et al. 2006). We briefly describe here the simplest case where two symmetric

[5] In practice, profits with a CfD are not completely independent of power prices. The point is that this dependence is weaker with a CfD than without a contract.

firms (i, j) compete in a Cournot spot market having already a given position in the forward contract market (Q_i, Q_j). Suppose that demand is linear and that units are normalised so that the price in the spot market is given by $p = a - q_i - q_j$ when generators offer quantities q_i and q_j. If production costs are fixed at c per unit and firm i holds an existing contract for an amount Q_i with a strike price of R, then the profit function for player i is

$$Profit_i(q_i, q_j) = (a - q_i - q_j)(q_i - Q_i) + R\,Q_i - c\,q_i$$

Thus, maximizing profits with respect to q_i , the optimal choice in the quantity sold by generator i is:

$$q_i \;\; = \frac{(a - c + Q_i - q_j)}{2}$$

such that q_i is increasing with the contract quantity Q_i . With this arrangement we reach an equilibrium price in the spot market of

$$p = \frac{(a + 2c - Q_i - Q_j)}{3}$$

This example shows that markets become more competitive when generators have a contract obligation at a fixed price. The reasoning behind this effect is observable in the extreme case of players signing contracts for quantities corresponding to the competitive outcome, whereby the spot market becomes perfectly competitive. Hence, contracts reduce the incentives for unilateral abuse of dominance.

Since the seminal work of Allaz and Vila (1993) showing the pro-competitive effects of forward contracts on spot market, the economic literature has focused on understanding why would generators sign any forward contracts knowing that it curtails their market power in the spot market (Newbery, 1998; Green, 1999; Mahenc and Salanié, 2004; Vazquez, 2012).[6] Despite of the fact that most of this literature agrees on the fact that existing forward contracts have a pro-competitive effect on the spot market, there are several different views concerning the ability of generators to behave strategically in the forward contract market and how this ability interacts with the spot market equilibrium. Indeed, behaving strategically in the contract market, firms can increase their overall profits in the forward contract market and the spot market; the total effect might thus be anticompetitive. Anticompetitive effects might result from market players shifting market power from spot markets to forward contract markets. The literature is not conclusive concerning this issue. The main point of divergence comes from the following aspect: the procompetitive or anticompetitive effects of sequential (forward and spot) trading mainly depend on whether spot market competition is modelled as a quantity or a price game[7].

Nevertheless, it is important to notice that this literature considers the existence of a forward contract market where prices and quantities in equilibrium are freely determined by market players. In some cases, market players refuse to sign forward contracts as they do not want to lose their market power in the spot market (Green 1999). This implies that the market alone will not provide

[6] Some authors (e.g. Le Coq 2004, Liski and Montero 2006) argue that forward contracts might help collusive behaviour. Although these works differ in the setup of their model, their basic message is quite similar: the repetition of the game (forward market – spot market – forward market – spot market) facilitates coordination strategies. These results cannot however be applied to the case of the CfD at the Hinkley Point C plant given that the contract is regulated and one-shot (there is no possible repetition of the game).

[7] If generators compete a la Cournot, they will sell forward contracts to compete more aggressively in the market, which increases their market share at the expense of other participants (Allaz and Vila, 1993; Bushnell, 2007). Pro or anticompetitive effects in a combined forward contract and spot market are not so clear in other models of competitive behaviours (Newbery, 1998; Green, 1999; Mahenc and Salanié, 2004; Vazquez, 2012).

(or at least not enough) forward contracts. To create procompetitive effects and to ensure the right level of contracting, several authors have proposed to impose forward contracts, i.e., to impose regulated forward contracts defining quantities and/or prices to generators in order to maintain the incentives to reduce market power in the spot market (see for instance Willems 2006, Willems & De Corte 2008, Vazquez 2012). This specific literature is more directly linked to the case of contract for difference at Hinkley Point C given that quantities and prices are regulated.

5.3 Empirical work

The procompetitive impact of forward contracting on spot market has also been studied empirically. These studies concern forward contracting itself, long term contracting, and/or some form of vertical integration. Note that all these arrangements have implications on the spot market similar to those of a contract for difference i.e., disconnecting fully or partially profits from the spot price.

Wolak (2000) finds that forward contracting may have increased aggregate output in the Australian electricity market and produced a procompetitive effect. McRae and Wolak (2012) provide empirical evidence to explain the behaviour of the four largest suppliers in the New Zealand electricity market. They conclude that: "*the presence of fixed-price forward contract obligations implies a dramatically diminished incentive to withhold output to raise short-term wholesale prices, despite the fact that the firm has a significant ability to raise short-term wholesale prices through its unilateral actions*".

Several studies have been realised on the Californian electricity market, where the lack of forward contracting (and the corresponding market power abuse) has been recognised as one of the main reasons of the 2000/2001 crisis. For instance, Bushnell et al. (2004, 2008) compare market performance in the three largest and oldest US electricity markets: California, PJM and New England. They find that similar horizontal structures can produce dramatically different outcomes under different contracts or vertical arrangements. Whereas the Californian market was less concentrated than the other two markets, its complete lack of long-term contracting contributed to it experiencing higher electricity prices. Similarly, Borenstein et al. (2002) and Joskow and Kahn (2002) document evidence of market power being exercised in California. Bushnell and Saravia (2002) find only modest market power being exercised in New England where vesting contracts have been implemented.

Some research works have focused on European electricity markets. For instance, Willems et al. (2009) investigate the German market and find that, after introducing forward contracts, a Cournot model produces a price closer to the perfectly competitive outcome. Furthermore, Willems et al. (2009) note that forward contracts will only reduce market power if the contract price is fixed. If the contract price is indexed on the spot market it will have no effect.

The impact of contracts on the spot market has also been studied for the British power market, in particular at the beginning of the electricity reform where some fixed-price (vesting) regulated contracts were imposed to certain generators. Many authors agree that the exercise of market power in the spot market was mitigated thanks to the existence of these contracts. For instance, Green and Newbery (1992) argue that: "*We have not yet observed price increases of this magnitude* [the magnitude predicted by a supply function equilibrium model]*, at least until September 1991. During this period, most electricity sales were covered by contracts that hedged the pool price, so that a generator would not affect its short-run revenues by raising its bids* .[…] *The present contracts were supervised by the Department of Energy and were based on costs, specially the cost of U.K. coal.* […]. *Once the present contracts expire, their successors are unlikely to keep prices down.*"

Von der Fehr and Harbord 1992 argue that: "*At vesting, on March 31 1990, 'contracts for differences' were placed between the two major generators and the regional electricity supply companies covering approximately 85% of the generators' capacities. These are option contracts under which the* *difference between the spot, or 'pool' price of electricity and the contract strike price is paid to the purchaser (i.e. the regional electricity company) on a specified number of units. These option contracts have significantly reduced the incentives of the generators to bid pool prices above the level of contract strike prices, since any difference between the pool price and contract strike prices is paid back to the regional supply companies in the form of a difference payment on the amount of capacity contracted for. One would therefore not expect to see the type of 'noncompetitive' bidding behaviour predicted by the theoretical model mirrored in the historical bidding data. By March 31 1991 however, a proportion of these contracts had expired (approx. 15%), and the rest are due to expire by March 1993. With contract coverage lowered to about 70% of the generators' capacities, 'strategic' or 'noncompetitive' bidding behaviour becomes more likely, and so one expects to see in the first year of operation of the new system, bids reflecting generation costs – since contract strike prices were chosen to represent expected marginal generation costs – and after February/March 1991 a possible change in 'regime' to more aggressive, noncompetitive bidding. It is precisely this kind of 'change in regime' that we see reflected in the data to April 31 1991, and which is described here.*"

Wolfram (1999) claims that generators were not raising prices to the level which their market power could have allowed, and that a high degree of contract cover was the reason. Gray, Helm and Powell (1996) link increases in Pool Prices (which rose each April between 1991 and 1993) to reductions in the generators' contract cover.

Finally, the procompetitive properties of fixed-price forward contracting have been taken into account in the analysis of different support schemes for renewable energy (see for instance Batlle et al. 2011). In particular, Feed-in Premium has been compared with fixed-price instruments (as Feed-in tariff or contract for difference). This literature suggests that Feed-in premium (which implies the payment of a premium on top of the spot price) has no procompetitive effect given that this instrument does not disconnect the spot price from the generator profits. In theory, under this scheme, the generator has incentives to increase the spot price in order to increase its profits. On the contrary, support schemes based on a fixed-price instrument (Feed in tariff or contract for difference) produce procompetitive effects (other things being equal).

5.4 Conclusions

This short literature review allows us to draw two conclusions:

1. Contracts for difference (and similar fixed price contracts) help to mitigate market power in the power market (reducing the incentives of generators to increase power prices)
2. Other instruments like Premium, that do not disconnect generators' profits and power prices, do not mitigate market power

These conclusions can be applied to the case of Hinkley Point C and specifically to the model of Green and Staffell. They are wrong when they state that (page 7) "*[in presence of market power], prices would be higher in all the cases [they present]*". If the model would have assumed imperfect competition in the power market, Contract for difference would allow to increase welfare with respect of a reference case (with nuclear but without contract). The Contract for difference would also have a higher welfare than the Premium.

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