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Varieties of coal-fired power phase-out across Europe

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ABSTRACT

Meeting climate goals is a particular challenge for countries that combine extensive use of coal as a fuel for power generation with a significant history of coal mining. We argue that these countries are prone to institutional carbon lock-in processes that significantly affect the phase-out of the use of coal. We use the analytical framework of Varieties of Capitalism to compare degrees of carbon lock-in in Coordinated Market Economies (CMEs) with Liberal Market Economies (LMEs). In CMEs "strategic interaction", "employment protection" and "government ownership" translate into protection of uncompetitive domestic coal activities and assets through (cross) subsidies and veto play. In LMEs the use of coal will be more dependent upon its market price in the international energy market. Through a qualitative comparison of the development of coal-mining and coal-fired electricity generation in three CMEs (Germany, Spain, Poland) and one LME (the UK) over the period between 1990 and 2017 we show that the UK's liberal market economy facilitated a relatively swift phasing out of coal mining and the use of coal, compared to a much more reluctant transition in the other three countries.

1. Introduction

To prevent the damages resulting from climate change, governments around the world have committed themselves to an energy transition that will require them to significantly limit the amount of greenhouse gases in the years to come (UNFCCC, 2015). This energy transition necessitates the deployment of two related policies: the adoption of new, less carbon-based technologies that replace the old technologies as well as phasing out the use of fossil fuels for generating electricity. This paper addresses how countries can phase-out coal more rapidly through analyzing which institutions present barriers to energy transition by hampering a coal-fired power plant phase-out.

Many countries by now have policies increasing the share of less carbon-based technology in electricity generation. Yet, this does not automatically imply that the amount of carbon-based electricity generation has decreased to the corresponding extent. Germany provides a good example. Between 1990 and 2015 the amount of electricity generated from renewables grew to 171 TWh annually. This however was not accompanied by a concomitant decrease in the use of coal; the use of coal only went down with an amount of 38 TWh annually between 1990 and 2017 (EC, 2019).[1]

The relatively poor decrease in the use of coal in Germany is a typical example of the phenomenon of "carbon lock-in", a self-perpetuating inability to change from existing carbon-intensive activities and technologies to less carbon-based activities and technologies in time to prohibit large scale damage from climate change.

In this paper we seek to shed more light on these lock-in mechanisms, by focusing upon the determinants of institutional lock-in, a form of lock-in which arises from "conscious efforts by powerful social, economic and political actors […] to reinforce a status quo trajectory that favors their interests against impending change" (Seto et al., 2016, pp. 433). Our analysis draws upon the explanatory framework of historical institutionalism (Lockwood et al., 2017) and that of the Varieties of Capitalism (VoC) literature in particular (Hall and Soskice, 2001). We argue that institutional carbon lock-in tends to be much higher in so-called co-ordinated market economies (CMEs). In CMEs it is difficult to quickly phase out existing carbon intensive forms of electricity generation because of institutionalized employment protection, government ownership and the room that consensual processes leave for key stakeholders to delay or block political decisions. Such institutions are much less supported in liberal market economies (LMEs), where ownership of energy supply is much more in the hands of the private

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[1] In 1990, gross electricity production in Germany amounted to 550 TWh, of which 311 TWh was coal-fired power and 22 TWh was renewable energy (nuclear and gas were other fuels). By 2015, electricity production was 647 TWh. Renewable energy had increased from 22 TWh to 193 TWh. The 171 TWh of growth in the use of this newer technology from renewables hardly crowded out the oldest technology, coal-fired power. Instead of a decrease in use coal-fired power of about 170 TWh, or even 70 TWh (accounting for overall growth), in 2015 coal was still used to generate 272 TWh of electricity, a mere 38 TWh less than in 1990 (EC, 2017).

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sector and governments leave it to market parties to choose the most efficient source of electricity supply. Additionally, the prevalence of majoritarian instead of consensual policy-making constellations in LMEs reduces the ability of interested parties to block policy-changes using institutional veto-points.

We investigate the effect of VoC type through a qualitative comparative process tracing of the phasing out of coal between 1990 and 2017 in four European countries: Germany, Poland, Spain and the UK. In section 2 we show how and why the VoC framework provides us with a better understanding of the institutional dimension of carbon lock-in. We argue that a proper understanding of lock-in processes for coal require a distinction between the extent to which countries are involved in coal mining and the extent to which coal is used as an energy source. After outlining the methodological set-up in section 3 we show in section 4 how in the CME countries the phase out of coal-fired power proceeded much slower compared to what happened in the LME setting of the UK. We also show how governments in the CME countries sought to prop up uncompetitive domestic coal mining through many decades of cross-subsidizing and how they repeatedly sought exemptions to EU regulations aiming to decarbonize the EUs energy provision.

After bringing together the results from the four cases in section 5, we draw conclusions and discuss policy implications in section 6.

2. Institutional constellations and policy-making

2.1. Varieties of capitalism and energy policies

The research paradigm that has been coined “Varieties of Capitalism” (VoC) (Hall and Soskice, 2001) advances a relational view of actors in the political economy by analysing the way labour interests, firms and government interact. In so-called “Coordinated Market Economies” (CMEs) markets are regulated to a considerable extent via formal institutions. CMEs provide for a cooperative infrastructure that allows for deliberation, information-sharing, the making of joint agreements, monitoring and sanctioning between firms, employees and the government. Because in CMEs trade unions and employment protection are relatively strong, labour interests exert considerable influence on the shape of these agreements. Ownership of firms in CMEs is less often in the hands of shareholders (Hall and Soskice, 2001). Where ownership of utilities is in the hands of governments, this make governments more directly responsible and accountable for operating decisions. As a result policy choices are susceptible to political influence of stakeholders, who may have veto player power to avoid policy changes that may be harmful to their interests (Tsebelis, 2002). Such institutional ‘constellations’ (institutional systems of political economy) may make it difficult to change the status quo and may slow down the process of adopting policy changes that are necessary in the light of new policy challenges, such as climate change.

In Liberal Market Economies (“LMEs”) coordination takes place primarily via market mechanisms, making it less feasible for governments and labour interests to reach long term agreements through collective bargaining. Equilibrium outcomes are determined primarily by relative prices and marginalist considerations, coordinated mainly through competitive markets. Trade unions are relatively weak and citizen's employment protection is relatively low, making labour markets comparatively fluid. Firms are owned more often through dispersed and private shareholding via stock markets. Through the dynamics of stock market value, management is incentivised to focus on current profitability and short term returns (Hall and Soskice, 2001). Empirical studies have confirmed the above distinctions (Hall and Gingerich, 2009; Schneider and Paunescu, 2012). There is a broad consensus that the UK fits the LME archetype and Germany fits the CME archetype, while data confirms that countries group around these archetypes for relevant socio-economic parameters like employment protection and ownership of firms (see Appendix Fig. 9).

If we apply the VoC-framework to climate and energy policy, we should expect that the varieties are visible in the organization of national energy markets, and that countries’ approach to the phase-out of coal mining and CFPP differs according to their VoC-type. Where in LMEs we expect that privatised ownership, stock markets and shareholders play a dominant role in firm activities, in CMEs we expect a stronger involvement of governments and labour interests in decision-making concerning electricity supply.

Several authors have shown how the type of VoC indeed affects the way countries are able to innovate through the introduction of low-carbon technology. Mikler and Harrison show that CMEs support incremental technological innovation with a long term focus and analyse this as a stimulus for the development and deployment of renewable energy technology (Mikler and Harrison, 2012).

Lachapelle and Paterson perform a broader small-N quantitative study of the impact that variety in institutional constellations has on national climate policy (Lachapelle and Paterson, 2013). They find that government intervention in markets, a democratic regime, parliamentary system and proportional representation positively affect the presence of climate policies like regulations, incentives, carbon prices, voluntary agreements and R&D.

Ćetković and Buzogány apply VoC in a qualitative, comparative study of the deployment of renewable energy technology in Germany, the UK and four nations in East Central Europe (Ćetković and Buzogány, 2016). They find that Germany's CME provided the best conditions for developing innovative mechanical and electrical products and facilitated Germany's comparatively strong growth in renewable energy and related technology.

While the studies above show us how VoC type affects the adoption of low-carbon technology, we should expect these institutional constellations to affect the process of the phasing-out of high carbon technology as well. Fossil fuel resources and assets that are created to exploit these resources, together with their end use, lead to “carbon lock-in”, a self-reinforcing inertia in the energy system. Seto et al distinguish three distinct types of carbon lock-in: infrastructural-technical, behavioural and institutional. Infrastructural-technical lock-in here is caused by the fact that power plants are stranded assets for which it is economically disadvantageous to write them off before their end of term. Behavioural lock-in refers to the way established modes of energy consumption and use hamper the adoption of alternative energy sources, for example through people's habits of cooking on gas-stoves. Institutional lock-in refers to the inertia that results from the way stakeholders that benefit from the status quo successfully use governance structures to maintain existing forms of electricity generation. As Seto et al note, through effectively mobilizing their interests politically these institutional lock-ins can reinforce and strengthen the other two types of lock-ins (Seto et al., 2016, p. 433).

2.2. Mechanisms of coal lock-in

Coal traditionally was the backbone of the energy system and therefore many European countries have a history of many decades or even more than a century of major investments in coal mines, coal shipping and transfer, and coal-fired power plants (CFPP). Generally, the domestic presence of fossil fuel resources leads to considerable investments in related infrastructure and assets over time.

Following Seto et al's terminology we coin the term “coal lock-in” to describe the degree to which a society is locked-in on investments, resources, assets and activities related to coal. In many European countries the activities, resources and assets related to coal mining and electricity generation fuelled by coal were historically ‘vertically’ integrated with electricity transmission and distribution, trade and supply.

The integrated nature of coal mining and coal-fired power aligns with the fact that historically the use of coal as an energy source was related to the ability to produce coal domestically. For example in 1991, Poland featured a 116% coal self-sufficiency and 78% share of

Table 1
Coal production, self-sufficiency and coal's share in primary energy in 1991, based on data from Anderson (1995). Self-sufficiency is the domestic production as a percentage of national coal use.

Country, 1991	Average annual coal production in millions of tonnes of coal	Self-sufficiency in coal	Share of coal in total primary energy use
Denmark	0	0	37
France	11	41	9
Germany	155	95	33
The Netherlands	0	0	12
Spain	16	60	22
Sweden	0	0	5
United Kingdom	76	87	29
Poland	124	116	78

coal in electricity production, whereas both the UK (87%) and Germany (95%) had high coal self-sufficiency and had about a third of primary energy use from coal (Table 1).

A first indication of lock-in processes at work is the fact that many countries in Western Europe kept their coal mines open despite the fact that coal mining became uncompetitive since the late 1950's, when the price of imported non-domestic coal fell drastically. Open-cast coal mines in Colombia, Indonesia, Venezuela, Australia and the US were producing coal that was up to 20 times less expensive to operate than the deep deposit production sites or "pit mines" in Western-Europe (Frondel et al., 2007). More recently, coal mining in Poland has become internationally uncompetitive as well (Barteczko and Lewis, 2016).

Particularly if domestic coal activities are uncompetitive, then degrees of strategic, non-market coordination become relevant to a study of national coal-fired power phase-out.

We can now formulate our hypothesis on how the institutional constellation and national coal resources determine coal lock-in as well as the climate and energy policy in a nation, shaping its energy transition to a sustainable energy system. In an LME we expect that availability of domestic coal leads to the domestic use of that coal in CFPP as long as incentives from market prices and climate policies support that choice. If the use of coal or domestic coal becomes more expensive than alternatives, we expect that through market coordination in a LME the electricity supply industry (ESI) opts for cheaper alternatives (e.g. imported coal, fracking, natural gas).[2] In general, in LMEs markets are more competitive, fluid and dynamic, and there is no a priori reason to expect otherwise for the energy industry.

In CMEs by contrast, market forces and climate policy are not the only concerns that drive decision-making surrounding the use of coal as an energy source. We expect that in CMEs governments will own coal mines or CFPP more often than in LMEs. This makes decisions to phase out coal-related activities essentially public decisions, which will be taken in political arenas and will involve a much wider range of considerations than competitiveness alone. A significant consideration concerns the protection of labour interests, those in coal mining in particular. Since CMEs typically display strategic interaction rather than market coordination, in CMEs we would expect labour unions and regional governments to be able to effectively slow down the phasing out of coal as an energy source in CMEs through strategic interaction. The ability to do so in CMEs is reinforced by the fact that politically these systems are usually of the consensual type, while LMEs are usually more majoritarian in nature (cf. Iversen and Soskice, 2009; Arsenault, 2017). Consensus systems give leverage to a wide range of players through coalitions and have many "veto players" (political actors or groups that can block policy, Tsebelis (2002)), while majoritarian systems, like the UK, have few; once a majority is in favour of a policy, it will be enforced.

Taken together, the room for veto play from governments and unions, the inclination towards subsidies and the resistance to liberalisation in CMEs would mean that the phase-out of coal-fired power in CMEs would take longer than in LMEs, given a sufficiently comparable material coal lock-in.

3. Methodology

To test our hypothesis it is necessary to engage in a comparative, longitudinal analysis of the phasing out of coal in CME and LME countries that have exhibited a relatively high and comparable dependence on coal, both in terms of coal mining and in terms of using coal as an energy-source. Fig. 1 compares several European countries regarding dependence on coal at our starting point 1990 and shows that four countries feature such a combination: Poland, the UK, Germany and Spain.

In terms of the type of the VoC classification for these countries the UK ranks as a LME, while the other three countries are CMEs.[3]

In section 4 we provide a country by country historic process tracing of the phasing out of coal in these four countries. Our analysis describes the historical trajectory of the use of coal as an energy resource as well as developments in coal mining. In the UK, our LME case, we expect a relatively fast phase-out of coal, as dictated by market forces and climate and energy policies. In the other three CME countries we expect a much slower coal phase-out, because stakeholders use the consensual political infrastructure to influence policy-making. First, where coal-related activities are uncompetitive, stakeholders will successfully argue for subsidies in order to maintain jobs and avoid loss of local dividends. We expect in CMEs a diverse set of domestic policies being rolled out in order to keep uncompetitive coal-mining afloat as well as the use of domestic coal for electricity generation.

Secondly, we expect that in CMEs climate and energy policies that are imposed through EU regulations will be met with more resistance and result in attempts to delay their implementation or receive opt-outs or temporary derogations. The relatively greater resistance of CMEs to implementing various EU schemes is a second way to demonstrate the impact of VoC type on decarbonization.

Three sets of EU policies are in particular relevant here. The EU Emissions Trading System (ETS), the Large Combustion Plant Directive (LCPD) and the Industrial Emissions Directive (IED). The ETS is basically a market-fixing approach to climate policy, that attributes a price to the externalised cost associated with CO2, claiming to create a "level playing field"[4] (Bryant, 2016). A cap was set on the total amount of greenhouse gases that can be emitted by the over 11.000 installations covered by the system, from industries causing 45% of all emissions in the EU, including CFPP. The cap is reduced over time so that the total of

[2] Our framework predicts that in a LME, market prices have more impact than stakeholders or employment protection have. In LMEs Australia and the US, where coal mining was internationally competitive for the past six decades unlike in the UK, we see coal's share of electricity generation fall by around one-sixth in the last decade (Staffell et al., 2018, pp.6). Coal in the US being replaced by cheaper shale gas and renewables, despite the Trump administration and stakeholders trying to prop up coal, confirms that indeed, market forces tend to prevail in a LME.

[3] We acknowledge discussions about different subcategorizations within the class of CMEs. But for this paper, we focus on the effects of LME-institutions supporting "arms-length" market coordination, low employment protection and high stock market capitalization and majoritarian decision making, as opposed to all the "less liberal market economies" listed by Schneider and Paunescu (2012), a set we simply refer to as "CMEs".

[4] Because of liberalisation and subsequent consolidation, the top 20 polluters in the ETS are responsible for 52% of ETS emissions from 2005 to 2012. There is a notable presence of governments as major shareholders in the largest polluters (Bryant, 2016). This state-ownership runs against the concept of a 'market' based climate policy, since governments have non-market routes to influence EU policies for allowances. Governments can directly negotiate national exceptions through strategic interaction.

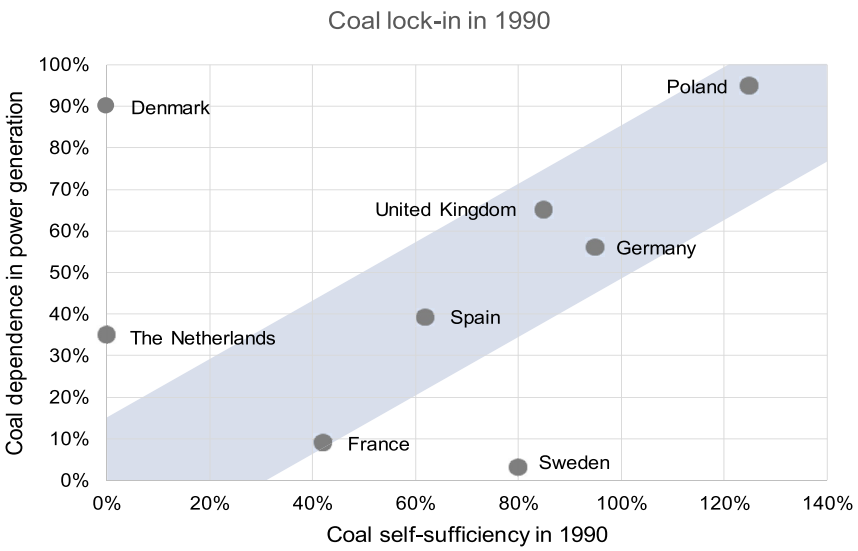

Fig. 1. Coal lock-in; self-sufficiency in domestic coal versus share of coal in gross electricity production per 1990, based on data from EC(2019).

CO2-emissions would fall. Within the cap, companies receive or buy CO2-emission allowances which they can trade with one another as needed.

The LCPD, introduced in 2008, is an air-quality directive which limits air pollution and directly affects CFPP. It has been asserted that between 2008 and 2015 the LCPD was related to the closure of 35 GW of CFPP capacity. It is difficult to assess whether or not these CFPP would have been closed anyway for age or other economic reasons. In 2016, two-thirds of Europe's CFPP are over 30 years old, with about 10 years to go (EIU (2017). Thirdly, the 2010 Industrial Emissions Directive tightens air pollution rules, focusing on nitrous oxides from a "the polluter pays" perspective, which increases the costs for running CFPP. It basically leaves Member States the choice to either modernize or to close the energy unit (cf. Sokolowski (2018)). All of these measures can be seen as additional challenges to the operation of CFPPs. Accordingly we expect CMEs to exhibit greater resistance towards implementing these directives compared to LMEs.

4. Coal-fired power phase-out in Germany, the UK, Spain and Poland

Even though in 1990 Poland, Spain and certainly Germany and the UK featured similar degrees of coal lock-in (see Fig. 1), their progress from 1990 to 2017 in escaping coal lock-in has been very different. The UK has made considerable progress, more than Spain and Germany, while Poland has made hardly any progress (see Fig. 2).

As a first step in the analysis, Fig. 3 provides a comparative overview of the absolute use of coal[5] as a fuel for electricity generation.[6] Coal use in all nations shows a degree of impact from the economic depression of 2008. Poland shows no decrease over the 27 year period in scope. The use of coal in Germany and Spain decreases slowly, but actually increased starting with the coal mini-boom of 2010-2012, until 2015. Considering intensified pressure for climate action, the EU ETS, the LCPD and the IED, these facts would seem unexpected. By contrast, in the UK the use of coal declined sharply after 2012.

Fig. 4 shows an overall decrease of domestic coal mining in all four nations. Increasingly larger quantities of cheaper imported coal have fuelled CFPP.

How can we account for these different trajectories and what has been the role of institutional lock-in in these processes? In the next sections we investigate case by case how the institutional constellations shaped the policies and events which affected the use of coal and coal-fired power. For each country we first describe the institutional constellation surrounding coal. We then trace the process of phasing out coal mining and the use of coal as an energy source and the political and market dynamics that surrounded this. Also we discuss how respective governments dealt with implementing EU regulations that affected the coal sector.

4.1. Germany and the coal penny

Germany is a political economy where government, firms and unions coordinate comparatively many actions through strategic interaction and non-market relations (Hall and Soskice, 2001). Privatisation and liberalisation of the energy sector are implemented in moderation. In 1990, after the reunification, the German electricity supply industry featured three types of firms operating at national (about 8), regional (about 40) and local levels (over a 1000, municipal utilities or "Stadtwerke"), under a mixture of municipal and private ownership. Also, vertical integration in the electricity sector (production, networks, trade, supply) is common (Newbery, 1995).[7]

German coal mining is located mainly in the region of North-Rhine Westphalia, one of the economically and politically most powerful Länder in the Federal Republic (a.k.a. "Ruhr district"), and Saarland. The underlying relation between government, firms and region is supported by the German political and social system. Typically German mineworkers' leaders are members of the Social Democrat Party ("SPD"). They regularly became members of the Federal and State parliaments, even as energy spokesmen for the SPD (Storchmann, 2004). This allowed affected employees direct political influence or "veto play" (Tsebelis, 2002). The powerful and influential trade union, "I.G. Bergbau und Chemie", represented the coal miners and was

[5] We show absolute use of coal as a fuel in TWh because it is a nation's absolute use of coal, not relative use or shares, that determines the actual output of CO2 and therefore the actual damage to climate.

[6] The global crisis of 2008 caused industrial activity and power generation to run lower than expected. It caused a dip in absolute use of coal in 2008 (cf. Fig. 3), which in turn caused a surplus of CO2-allowances and a low CO2 price. Emissions ran increasingly below annual caps and by December 2016 the ETS carbon price was around €5, compared with €29 in July 2008. As a result the ETS has provided little incentive to phase-out CO2-intensive CFPP (EIU, 2017).

[7] Functional unbundling was required under the EU Third Energy Package in the late 2000s (for utilities with more than 100.000 customers), but did not rule out governments from simultaneously owning grids as well as production facilities.

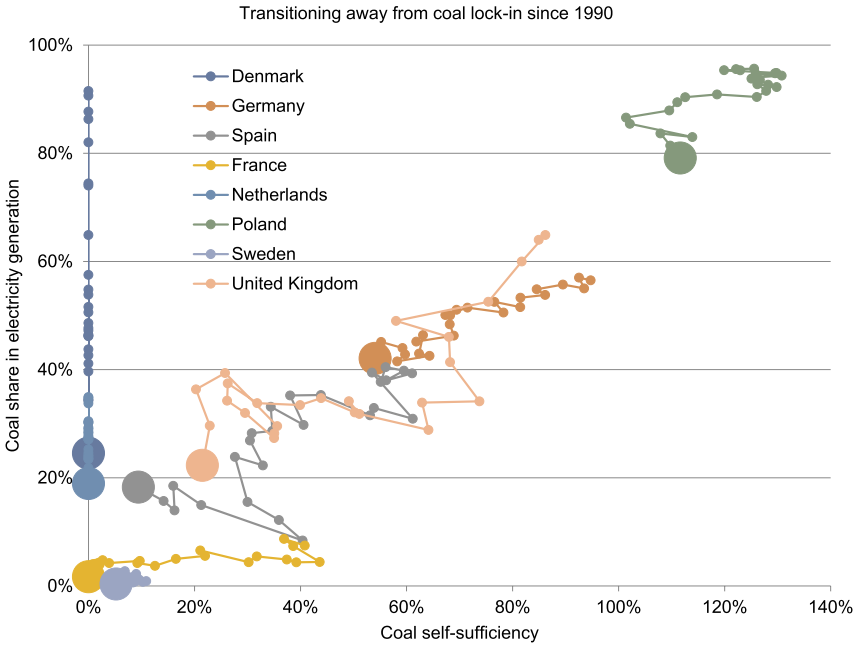

Fig. 2. The development of coal use in power production versus self-sufficiency in coal for eight European nations from 1990 to 2015 (dots representing years and the big dot 2015), based on data from EU (2019). It shows how generally coal use in the power sector is fairly resilient to the decline of domestic coal production.

closely affiliated with the SPD (Renn and Marshall, 2016).

Headquarters, history and partial government ownership of both E.On and RWE are situated in North Rhine-Westphalia. Regional municipalities are RWE's single largest shareholder, owning 23% or more shares in RWE for decades, 14% through RWEB GmbH, while 68% is dispersed (Handelsblatt, 2017). RWE tops the ranking of CO2-emitters in the EU ETS (section 3) companies database with 7% of 2005-2012 EU ETS emissions, E.On is second with 5%. Both companies were strong supporters of the EU ETS and used the EU ETS mechanism to defend their existing CFPP instead of investing in renewables, particularly RWE (Bryant, 2016).

In the 1990s, growing awareness of climate change in all political parties led to a consensus on climate protection goals. In fact, by 2007, it was the German government that moved the EU-leaders to agree on the 20-20-20 targets, aiming for a 20% share of renewable energy sources in the EU's primary energy supply by 2020 (Hake et al., 2015; EU, 2009).

Fig. 5 provides an overview of German electricity generation over time. The steep increase in renewable energy in Germany from 1990 to 2017, pushed by strong government policy, was not accompanied by a concomitant decrease in the use of coal as a fuel (cf. Fig. 5, also footnote 1). Because of an increase in demand and in the use of renewable energy sources for electricity generation, only in relative terms has the share of coal in Germany really diminished over these 27 years (cf. Appendix, Fig. 10a).

Why has the phasing out of coal been so limited? The Federal government enabled support for coal mining in 1990 by having electricity firms agree to use 40 Mt of domestic hard coal per year ("Jahrhundertvertrag") and compensated the electricity firms for not using cheaper imported coal (Newbery, 1995). For decades coal subsidies were funded through a coal levy, the "Kohlepfennig" or "coal penny" paid by electricity consumers. The coal penny was a regulatory

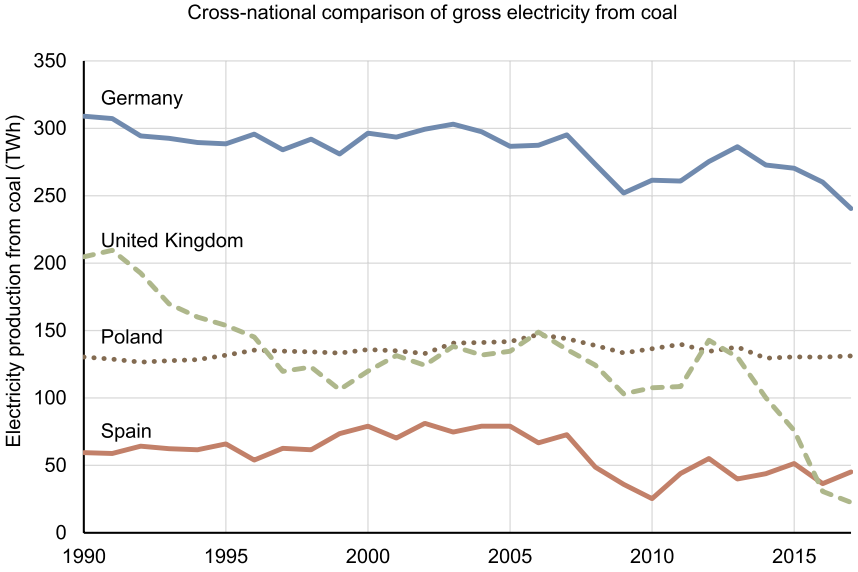

Fig. 3. Use of coal for power in TWh, 1990–2017, based on data from EU (2019).

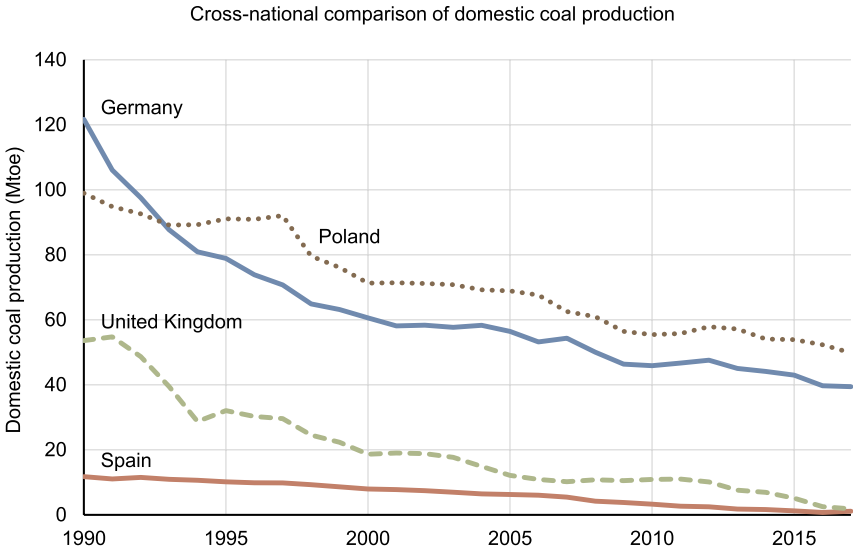

Fig. 4. Domestic coal mining, 1990–2017, based on data from EU (2019).

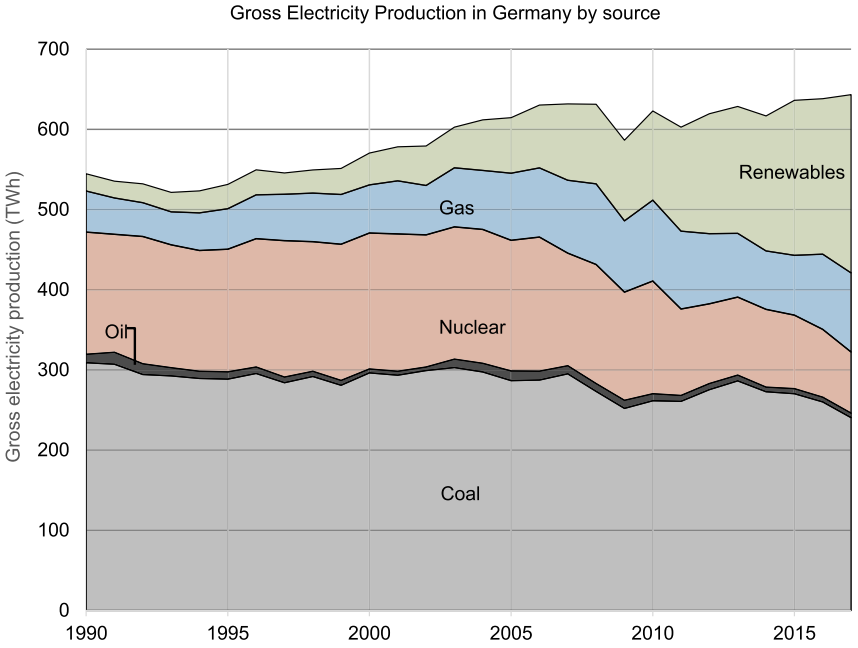

Fig. 5. Gross electricity generation in Germany by fuel in TWh based on EC (2019).

measure from a collection of over a dozen, where regional governments (North Rhine-Westphalia, Saarland) and Federal government together allocated public money to support firms and citizens dependent on coal mining.

Introduced in 1975 after the Oil crises, the coal penny averaged 8.5% of the price of electricity by 1995, about 3 billion euros per year in payments to electricity utilities. Overall it generated a subsidy volume of 37.2 billion euros (Storchmann, 2004). In 1990, government assistance per coal miner employed was almost 90.000 US$ for Germany (Anderson, 1995). It was only in 1994 that the coal penny was abandoned, through a ruling of the Federal Constitutional Court that declared it unconstitutional. As a response to this the Federal government, the regional governments, mining firms and the mining trade union agreed on hard coal subsidies in March 1997. The federal subsidies decreased from 4424 million in 1998 to 3408 million in 2002, but were compensated by increased regional funding by North Rhine-Westphalia. Halfway, in 2000, Germany featured the largest subsidised hard coal production of OECD countries with 4000 million euros (Storchmann, 2004). This amount of state aid around 2000 is remarkable in the light of the West-European liberalisation, globalisation, cheaper imported coal and the corresponding decline of domestic coal production (see Fig. 4) between 1990 and 2000.

By Spring of 2003 the regional government of North Rhine-Westphalia established a 20 Mt guarantee, but was overruled by the Federal government in July 2003. Because of budget constraints the target was set at 16 Mt per year. This amounts to an annual subsidy payment of around 1.6 billion euros (Storchmann, 2004).

In 2010, Germany asked the EU to extend acceptance of financial support for coal mining until the end of 2014 (Abend, 2010; EU, 2010a). North Rhine-Westphalia and the federal government, through intense negotiations, agreed on a base production after 2010, motivated by them as necessary to secure the energy supply. This agreement coincides with the 2010 increase of the share of coal in the fuel mix for gross electricity generation in Germany, cf. Fig. 5. As discussed in footnote 1, Germany started to export electricity when it could have shut down CFPP, even while simultaneously the Energiewende called

for the phase-out of nuclear energy.

With many nations to import cheaper coal from, coal subsidies in Germany basically amount to the public sector providing jobs (Frondel et al., 2007, pp. 3810). This aligns with the high degree of employment protection established for Germany as a CME (Hall and Gingerich, 2009), as does the strategic interaction between Federal government, local government, unions, employees and firms that led to subsidies, quota's and state aid.

Under the IED, Member States can propose a plan to either modernize energy units or opt for lifetime derogation. However, by 2017, the EU Commission has raised objections to Germany's proposed plan (cf. Sokolowski (2018), pp. 268, fn. 33). By 2018, Germany's federal government has set up a "coal exit commission" consisting of government, civil society, business and labour unions to manage the phase-out of CFPP. A large part of the discussion, with former prime ministers of industrially weak East-German lignite-mining states in the commission, is about compensation to firms and to regions (Wacket, 2018). This process is in alignment with the institutions we have described; "employment protection", "government as a shareholder" and "strategic interaction". January 2019 a deal was closed, stating that compensation and other shutdown details should be agreed between the government and the CFPP operators on a contractual basis (Wacket, 2019), which aligns with strategic interaction, not with market coordination.

4.2. UK liberalisation, the dash for gas and carbon price floor

In accordance with the UK's LME type of political economy, it features a liberalised energy market with private ownership. After liberalisation as early as 1990, a series of mergers and the entry of large foreign multi-national utilities led to the emergence of ten generation companies, owning 85.8% of UK generation assets by 2012 (Hall et al., 2016). In the 1990s England and Wales moved into an unprotected and privatised coal sector, selling coal to a restructured, vertically unbundled and generally privatised electricity sector (Newbery, 1995).

The roots of these changes can be traced back to the election of Margaret Thatcher in 1979, which firmly placed market ideology at the core of government policies. The state became strongly adverse to aid for coal mining and allowed the electricity industry to gradually increase the imports of cheaper foreign coal, considerably earlier than in Germany. Financial aid to coal mining became conditional on deep restructuring. The move under Thatcher against coal and the power of unions was motivated by political reasons (cf. Helm (2003), pp.155–156) as well as from a policy paradigm and was enabled by the majoritarian political system.

Tension with labour unions escalated which led to the year-long Great Miners' Strike of 1984-1985, a major industrial dispute in British history, where the unions were defeated by the single-party Conservative government. It led to the closure of many British coal mines and a diminished position for trade unions. Political pressure led to downsizing and restructuring of the coal industry from the mid-1980's. Government policies were aimed at privatisation and a competitive coal industry free from subsidies, resulting in the 1985 National Coal Board's "New Strategy for Coal". The chairman of NCB appointed by Thatcher accelerated mine closures and showed little concern for social implications and mining communities, like those in Yorkshire (Turnheim and Geels, 2012). In the early 1990's though, UK government assistance to coal production was still equivalent to providing a domestic producer price 40% higher than the import price, 38.000 US$ per coal miner employed (Anderson, 1995). But by December 2015, the UK's last deep coal mine was closed in Yorkshire, putting an end to the UK's coal lock-in regarding domestic coal mining (BBC, 2017). In line with our expectations the decrease of coal use in the UK was comparatively fast, cf. Fig. 6 (also Appendix, Fig. 10b).

The decline of the use of coal was strongly facilitated by the increased competitiveness of natural gas as an alternative. In the early 1990s the then still-regulated Regional Electricity Companies were able to access long-term fixed price contracts from the UK's own domestic gas resource in the North Sea and largely built the combined cycle gas turbines or "CCGTs" (Helm, 2003, pp167-168), making use of technological advances in gas turbine generators. When the electricity market was liberalised and the prices of natural gas fell in the late 1990s, market dynamics diminished the demand for coal-fired power. Technological advances in gas turbine generators and financial advantages of building gas-fired power plants made them a more competitive choice for market players. This policy paved the way for investment in this competitive gas technology and subsequently the UK's "dash for gas", breaking the electricity utilities' lock-in on domestic coal as they turned to CCGTs.

The privatisation also doubled the import of cheaper foreign coal from roughly 10% in the decades before to roughly 20% between 1992 and 1997. Employment in coal mining fell from 49.000 in 1990 to 10.000 by 1996 (Turnheim and Geels, 2012), as the dash for gas saw 100 TWh a year of coal-fired power generation and about 40 million tonnes of coal replaced by CCGT's (Staffell, 2017). At the end of the 1990s, a newly elected Labour government implemented a temporary ban on the construction of new CCGTs, which was in fact a modest form of support for coal.

The UK embraced CO2-reduction with the adoption of the 2003 White Paper "Our Energy Future: Creating a Low-Carbon Economy". The ambitious 2008 "Climate Change Act" adopted carbon budgets that were in line with the 2020-targets and a 80% greenhouse gas reduction for 2050 compared to 1990. Nonetheless CO2-emissions from electricity generation did not decrease between 2000 and 2012. Coal-related firms promised the government and the public 'clean coal' and 'innovation' through carbon capture and storage (CCS).

Prices for oil and gas were rising, and the 2005 conflict between Russia and Ukraine caused problems with Russian gas supply. The lower prices for coal made utilities more interested in coal in the periods of 1999-2006 and 2010–2012 (Geels, 2014), causing two coal 'revivals' (Fig. 6). Market circumstances determined the use of coal. The price of coal and gas stayed roughly in line until 2011. After that, cheap imports of coal meant that the price of coal fell to about 60% of the price of gas.

The UK's more market based approach resulted in a greater effect from environmental requirements as set by the EU air-quality directive "LCPD", which meant that CFPP running hours were to be restricted. As a result, in the UK building new CFPP was considered risky because of recent climate policy. In fact, political pressure from campaigning NGOs to prevent new CFPPs being built (specifically the Kingsnorth plant) successfully led to the Labour majority government banning new CFPPs without CCS in 2009. By then, unlike in Germany, there was no active political pressure from unions, firms or governments left in the UK to support coal-related investments. EU policies in the form of the LCPD and its successor, the 2013 EU Industrial Emissions Directive ("IED") resulted in the forced retirement of several CFPP. The IED offers the option for lifetime derogation for energy units, and January 2016 the UK decided to use this derogation for 12 named power stations (cf. Sokolowski (2018), pp. 269).

But most responsible for the decrease of coal use in the UK from 2013 was the introduction of the carbon price floor ("CPF"). Not directly required by EU policies, we analyse it as an example of a national market-fixing policy that, like the ETS, attributed a price to the externalised costs of CFPP. It tripled the cost level for CO2 of the EU ETS. This high national carbon tax brought coal and gas prices in line with one another and made it more difficult for coal to compete (Staffell, 2017). It was enabled further by available gas supply infrastructure and by coal and gas prices being sufficiently close, particularly in 2016. The CPF was implemented in March 2013. Decades of pressure on coal paved the way for the spectacular reduction of 25% of emissions from the UK electricity sector between 2015-2016 (6% of emissions nationwide), through the CPF driving rapid fuel switching (cf. Wilson and Staffell (2018)). When the CPF doubled in April 2015, the share of coal

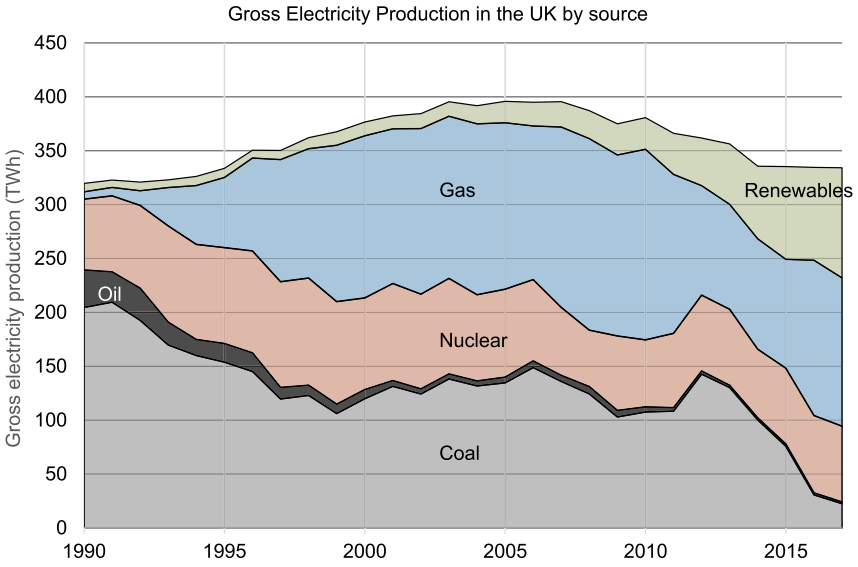

Fig. 6. Gross electricity generation in UK by fuel in TWh based on EC(2019).

in the UK fuel mix took another deep dive (Fig. 6). April 2017 Britain experienced its first coal-free day since the 1880s (BBC, 2017). January 2018, the UK government announced that CFPP will have to close, unless their CO2 emissions are no higher than 450 kg/MWh at any time, from October 2025 onwards (Twidale, 2019). This makes building new CFPP pointless.

4.3. Spain and the Royal Coal Decree

In "statist" nations like Spain, strategic interaction in corporate governance and labour relations is higher than in LMEs (Schneider and Paunescu, 2012, see Fig. 9). This is reflected in the ownership structures for the electricity sector in the early 1990s. We see a mixture of large state- and private-owned firms, the most obvious example being Endesa: 75.6% held by the state, the rest privately (Newbery, 1995). Already after the Spanish Civil War (1936–1939), protection of non-competitive domestic coal mining was concentrated in the state-owned utility Endesa. Endesa concentrated on coal and lignite as fuel for CFPP, mostly in the Northern regions that produced coal. In 1985 the government organised an asset swap that transferred assets from smaller and weaker firms to state-owned Endesa, which had a 40% market share around 1995.

Typical for strategic interaction was the 1988 "Marco Legal Estable", a framework that remunerates electricity utilities using a concept of standard costs. Also, in Spain vertical integration in the electricity sector and even backward into fuel supply remained common. Linkages involve explicit state ownership but also long term contracts (Kahn, 1998).

The entrance of Spain into the EU per 1986 started a gradual decline of the coal mining industry in Spain. Policies for substitution of coal in the fuel mix were indirect: through supporting other technologies (Fig. 7). In Spain, between 1990 and 2010, renewables and natural gas replaced coal and nuclear in the fuel mix for electricity generation in relative terms (cf. Appendix, Fig. 10c). In absolute terms though, coal-fired power hardly decreased from 59,7 TWh to 51,4 TWh yearly (cf. Fig. 7). Despite the EU ETS, LCPD and IED (section 3), coal even replaced natural gas in the fuel mix for electricity generation between 2010 and 2015. Direct government intervention revived the use of coal at a relatively late point in the energy transition pathway.

Coal is the only domestic fossil energy source in Spain and coal mining has played an important role in Spain's energy history. In 1990, Spain featured 200 mining companies and 45.000 employees producing 35.8 Mt of coal. Spain's phase-out policies focused on benefits and subsidies, not on creating new jobs (Zafrilla, 2014). With the highest unemployment rate of any advanced economy, regional labour impacts of power plant closures would be severe.

When in 1996 coal stock was piling up, the Ministry of Energy and Industry ordered fuel quotas to eliminate this oversupply, reducing market share for nuclear and hydro power (Kahn, 1998). This amounts to direct government intervention in markets to protect employment.

The 1997 "Ley del Sector Eléctrico" introduced competitiveness in the electricity sector and the expansion of renewable energy (Zafrilla, 2014). Simultaneously, in 2000 Spain featured the second-largest subsidised hard coal production of OECD countries with 0.7 billion euros (Storchmann, 2004).

The EU Council Regulation of July 2002 (EC 1407/2002) discouraged state aid to coal mining but made an exception for Spain, because of the importance of coal to Spain's electricity production (30%). As both the EU Regulation and the exception for Spain were about to expire by December 31st, 2010, in the fall of 2009 Spanish prime minister Zapatero, from coal region León, proposed a Royal Decree to have Spanish CFPP use volumes of domestic coal. However, May 2010 the EU agreed on a policy stopping member states' financial support for uncompetitive coal mines unless the aid was accompanied by a plan to close said coal mines.

The Spanish domestic coal mining industry, reduced to 5000 employees by 2009, faced decreasing demand for coal as Spanish utilities overwhelmingly purchased cheaper, imported coal. By July 2010 the two largest coal mining groups in Spain stopped paying their workers, citing lack of funds. This was followed by a series of miner protests known as the "Black March" and strikes in September 2010. Spain asked the EU to extend acceptance of financial support for coal mining until the end of 2014 (Abend, 2010; EU, 2010a).

The EU agreed that Spain could support domestic coal mining until December 31st, 2014 at the latest, provided the share of electricity concerned remained below 15% (EU, 2010b). The Royal Coal Decree became effective in February 2011. The Spanish government obligated 10 specific CFPP to burn specified volumes of domestic coal for a specified reimbursement per MWh to the firms (ICIS, 2010). It was clearly strategic interaction, not market coordination which supported this increase of the use of coal.

The EU extension of acceptance of support for coal mining to the end of 2014 benefitted the coal producing regions of Asturias, León and Teruel. It was influenced by electoral incentives (Zafrilla, 2014). Electricity companies Endesa, Iberdrola and Natural Gas Fenosa as well as the region of Galicia appealed against the Royal Coal Decree

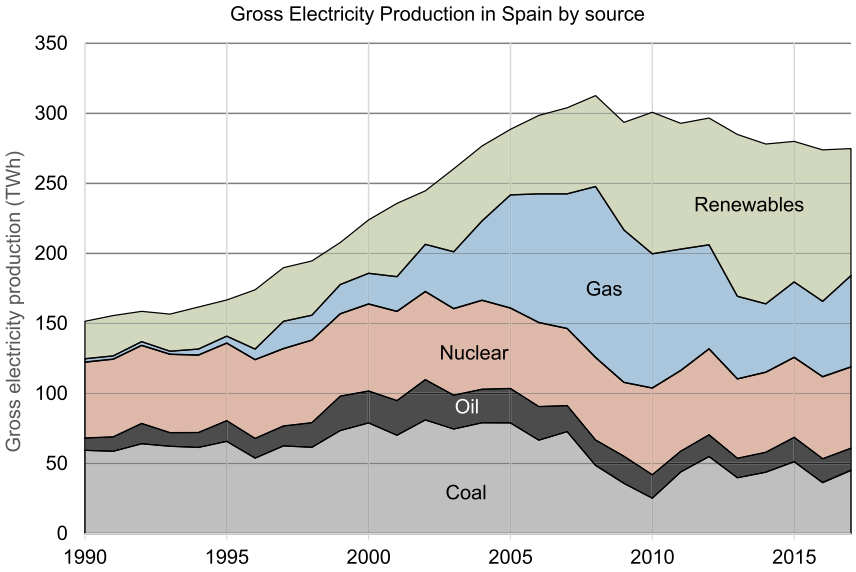

Fig. 7. Gross electricity generation in Spain by fuel in TWh based on EC (2019).

unsuccessfully (ICIS, 2010). In that way, political influence or "veto play" (Tsebelis, 2002) from regions and employees blocked the demise of domestic coal use in Spain, enabling a revival in the use of coal as late as 2010. The EU extended this acceptance to the end of 2018.

But more recently Spain established a plan for modernization of energy units under the IED that was accepted by the EU (cf. Sokolowski (2018), pp. 268). September 2018, Spain agreed to an EU proposal that effectively bans State aid for coal (Simon, 2018). October 2018, Spain decided to close most of its coal mines, after government and unions struck a deal with the EU that will mean €250m will be invested in mining regions over the next decade, early retirement for miners, re-skilling and environmental restoration (cf. Nelsen (2018)). With domestic coal providing just 2.3% of Spain's electricity, the political impact was not a problem for the new Labour government.

4.4. Poland and coal dependence

After communism, Poland developed a democracy built on proportional representation and multi-party coalitions which functioned between 1990-2015. Successive multi-party Polish governments were strongly in favour of coal and CFPP. The right-wing Law and Justice party ("PiS") elected in 2015 was the first single party majority in Polish parliament since 1989 and featured an even more hard-line position in favour of coal (Marcinkiewicz and Stegmaier, 2016; Schwartzkopff and Schulz, 2017).

Most industrial sectors in post-communist countries did see a large-scale privatisation. In the early 1990's, the Polish energy sector began with the launching of privatisation as well. However, later in the 1990's Poland established state-owned companies to operate individual power plants. After Poland entered the EU in 2004, these state-owned companies were consolidated, and, in 2006, vertically integrated in order to improve financing prospects for investment requirements. State-owned PGE was formed between 2004 and 2007, bringing together the most polluting installation in the EU ETS (section 3), the 5400 MW coal-fired Belchatów power station, with the Turów, Opole and Dolna Odra CFPP (Kaminski, 2012). This centralised 70% of the Polish state's EU ETS emissions in one state-owned company and made the government of Poland directly responsible for 674 Mt CO2 or 5% of the EU ETS emissions between 2005 and 2012 (Bryant, 2016).

Four of the other consolidated companies were privatised, paving the way for some Foreign Direct Investment from multi-national energy companies. However, firms with a decisive amount of shares owned by the Polish state (one 50%, four more than 75%) serviced over 75% of the Polish electricity market (Kaminski, 2012, pp. 139). Four out of five hard coal mining companies in Poland are owned by the Polish state, linking these firms to considerable political influence or "veto play" (Tsebelis, 2002). The Polish state has a direct financial stake in the success of the coal industry. Also, coal sector unions in Poland have a history of being remarkably powerful, with 240 trade unions for 100,000 coal jobs having significant political power (Schwartzkopff and Schulz, 2017).

Poland's electricity supply industry is strongly dominated by coal as a fuel. Though in relative terms natural gas and renewables did replace part of coal's share in the fuel mix between 1990 and 2017 (cf. Appendix, Fig. 10d), in absolute terms, coal remained exactly stable (Fig. 8).

In the early 1990s, because of geophysical and economic differences, the coal lock-in in Poland was different. Polish coal mining was internationally competitive. Poland's domestic prices for coal and electricity were far below the price levels for imported coal from the US, whereas they weren't in Western Europe (see Table 2).

Poland had coal seams which were internationally competitive to mine, so there was no need for subsidies or obligations for the use of domestic coal in electricity generation. The government in Poland though, as owner of the hard coal mines, continued to make significant losses (2 billion US$ during 1991-1993). Essentially, Polish electricity users were subsidised then by the Polish government through having domestic coal prices of just about half the border prices (Anderson, 1995).

Poland has a history of being dependent on gas and oil imports from Russia: in 2014 90% of oil imports and 65% of gas. Poland's priority is to become as energy independent as possible, making "energy security" the guiding principle for Polish energy policy. Its key problem is financing the necessary investments, as many power plants are end of life while energy demand is increasing. In 2014, 40% of Poland's CFPP were over 40 years old, about half of them to be phased out by 2030 because of technical constraints and environmental constraints like the EU LCPD and IED (Piria et al., 2014).

Polish coal mining is strongly concentrated in the south-west region of Silesia and, as in Germany and Spain, regional concerns around coal carried politicians into government. In 2015 Prime Minister Beata Szydlo swept to office in October with PiS on a promise that she would protect the coal industry's 100,000 jobs. She is a coal miner's daughter from the region of Silesia, home of the now suffering state-owned Kompania Weglowa (KW), the EU's biggest coal mining company (Barteczko and Lewis, 2016).

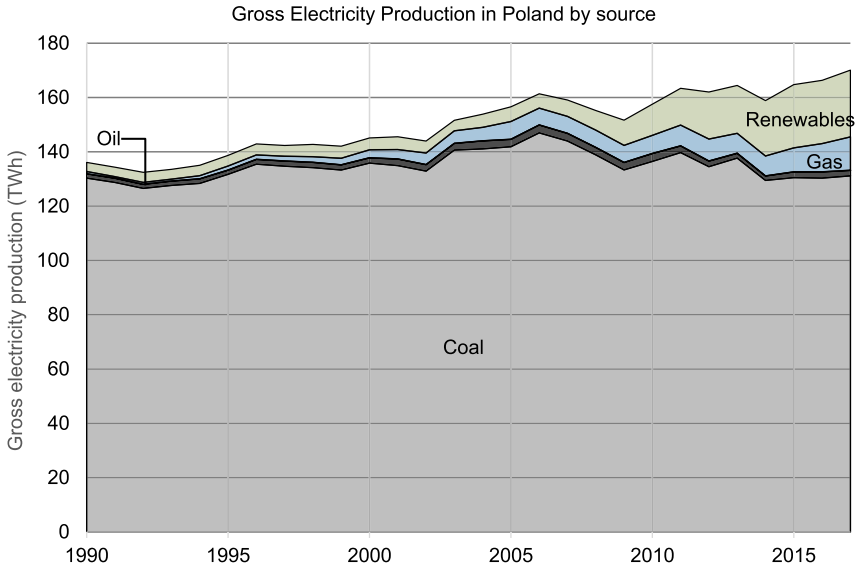

Fig. 8. Gross electricity generation in Poland by fuel in TWh based on EC(2019).

Table 2
Coal price for industry and coal price for electricity relative to the US 1990–1992 (US = 100), based on data from Anderson (1995).

Country 1991 (US = 100)	Coal price for industry	Coal price for electricity	Electricity price for households
France	234	130	191
Germany	459	377	205
UK	212	227	144
Poland	81	55	33

The IED offers the option to modernize CFFP, and Poland offered 47 energy units for modernization instead of lifetime derogation. For Poland's leading lignite-fired power plant "Adamów", Poland wanted to take advantage of the higher limit of operating hours (32,000 instead of 17,500) under the IED, in December 2015; however the EU turned this request down (cf. Sokolowski (2018), pp. 269).

Since 2015, Polish coal mining productivity has declined and the coal mining sector is in financial trouble (Schwartzkopff and Schulz, 2017). Polish firms that are forced by the state to help the suffering coal companies are now losing value themselves, and citizens face having to bear losses (Barteczko and Lewis, 2016). Essentially citizens and firms now subsidise coal mining and CFPP, something which underlines the strategic interaction type of coordination that characterizes the CME variety of capitalism of Poland.

5. Discussion

The comparative longitudinal analysis of the phasing out trajectories in the four countries clearly shows that the coal policies in the three CMEs have been significantly different from those that evolved in the UK, our LME case. First our analyses shows that there is a very good fit between the typology of political economies of the VoC-framework (section 2.1) and the ownership structures in the different countries. All three CMEs feature a vertically integrated electricity sector from the 1990's on with government ownership, either regional and municipal (Germany) or state (Spain, Poland). In LME the UK the electricity sector is privatised and unbundled.

Secondly, these ownership structures in turn have set the scene for strategic interaction in CMEs. It has enabled regional stakeholders to prolong the use of coal in Germany (North-Rhein Westphalia, section 4.1), in Spain (Leon, section 4.3), and Poland (South-West region of Silesia, section 4.4). In our LME case the UK we did not see similar strategic interaction: local concerns from the region of Yorkshire were not able to block the phasing out of coal-related activities (section 4.2), because of the prevalence for market coordination in the UKs government approach to energy policy.

Thirdly, our analyses have confirmed that in CMEs institutional support for employment protection is stronger (section 2.1). Spain and Poland displayed direct government intervention to protect coal mining jobs (sections 4.3, 4.4). Germany intervened more indirectly, through arrangements involving regional governments, unions and specified volumes of domestic coal (section 4.1). The UK as a LME typically displayed the lowest support for employment protection, as confirmed by the way the Thatcher government responded to the Great Miners' Strike and its lack of support for coal activities (section 4.2).

Fourthly, the patterns we expect for subsidies to coal are also confirmed by the data. Coal mining has been uncompetitive in the UK, Spain and Germany since 1958. In Spain, in 1992, coal was sold to CFPP under protected contracts at prices over 3.12 times those in the UK and 1.42 times those in Germany in 1989 (Newbery, 1995). The higher Spanish and German coal subsidy policies align with strategic interaction (CME), whereas the UK's policy aligns with market coordination (LME).

Regarding coal dependence, we must note that the availability of domestic natural gas sets the UK apart from the other three nations. However, the UK's liberal policies for limiting coal aid and reducing protection date back to the earliest 1980s, preceding the 1990's dash for gas (section 4.2). We contend that the UKs early reduction of aid for coal mining is in line with its institutional constellation supporting market coordination.

The UK had the option (87% coal self-sufficiency) to stick with the 1991 status quo in coal jobs and dividends, just like Germany (95% coal self-sufficiency) and even more so than Spain (60% coal self-sufficiency), cf. Table 1. The availability of domestic natural gas did facilitate the UK's policies to abandon coal. Wilson and Staffell hold that it was the price on carbon which was the main driver for coal's final rapid substitution starting April 2013, enabled further by available gas supply infrastructure and by coal and gas prices being sufficiently close, particularly in 2016 (cf. Wilson&Staffell (2018)).

The late increase in coal use in Spain and Germany between 2010 and 2015 (Fig. 3), despite the EU climate policies (section 3), illustrates the resistance of CMEs to implement climate and energy policies as demanded by the EU. Where in 1990 the UK and Germany were quite similar in terms of coal lock-in (Fig. 1, upper right quadrant), by 2015 the UK had moved to a situation of comparatively low coal lock-in

(comparing Figs. 1 to 2). Comparatively, by then Germany had moved considerably less from its 1990 situation of coal lock-in than the UK. We contend that because of its institutional constellation Germany was comparatively more constrained to change its situation. The same goes for Spain, but from a better starting point. Also, by 2015, Poland has become even more of an outlier because of its institutional constellation and its material coal lock-in.

6. Conclusions and policy implications

Coal has a huge impact on climate change (Erickson et al., 2015). With the UNFCCC Paris Agreement of December 2015, the global community has chosen to address climate change through voluntary Nationally Determined Contributions (NDC's) (UNFCCC, 2015). As a consequence, nations in a situation of coal lock-in are asked to voluntarily phase-out coal and CFPP. As has become clear from this paper, this means that a number of CME-like nations will have to challenge deeply-rooted institutional constellations that have so far supported coal-related government interests, employment protection, regional concerns and preferences for strategic interaction for about six decades, even when market considerations suggested otherwise.

Previous studies have found that CMEs do better in having countries adopt new carbon neutral electricity generation techniques (Mikler and Harrison, 2012; Lachapelle and Paterson, 2013; Ćetković and Buzogány, 2016). Our study shows that it is these same institutional constellations in CMEs that make it difficult to disband older types of electricity generation. CMEs might only be able to phase out coal through consensual agreements that require extensive compensations and side payments in order to compensate for job losses and for writing off sunk assets. However, the success of the Carbon Price Floor in phasing out British coal (section 4.2) suggests that a majority for a significant carbon tax might lead to results considerably faster.

We view the introduction of the carbon price floor ("CPF") as an example of a typical LME-style "arm's-length" market-fixing policy. The CPF builds externalities into the electricity price indiscriminately for all players in the national energy market. By contrast, CMEs lean on strategic interaction amongst relevant stakeholders, enabling specific agents to use veto play and slow down the process. Both our theoretical model as well as the data suggest that the UK's approach with an arm's-length carbon tax like the CPF which indiscriminately applies to the entire market is more successful.

This paper has contributed to the awareness that deployment of low-carbon technologies is but a part of the climate challenge, and the phase-out of existing carbon-intensive technology is a topic that is at least equally relevant and deserves further study. As Seto et al rightly note processes of lock-in "pose significant obstacles to adoption of less-carbon-intensive technologies and development paths" (Seto et al., 2016, pp.445).

Overcoming institutional carbon lock-in is especially difficult as institutions are sticky and hard to change in the short run. Still, even in situations of considerable lock-in, changes may be on the horizon. First, technological advancements may make a further decarbonization more feasible. Secondly, institutional stickiness may be overcome through bursts of disruption as a result of swift social, political or technological changes, that make it unfeasible for veto-players to still block decarbonization (Seto et al., 2016, p. 446]). Thirdly, the very institutional framework that is responsible for the slow phasing out of coal in CMEs also provides for a consensual deliberative infrastructure that allows a soft-landing type of exit from coal dependency. As the recent developments in CMEs Spain and Germany show, this can be achieved through negotiated settlements with labour interests and affected regions, involving considerable side-payments to compensate for the loss of jobs and revenues associated with the use of coal as an energy source. While these agreements are costly in the short run they form an indispensable element in facilitating the transition to a carbon-neutral energy future.

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Appendix

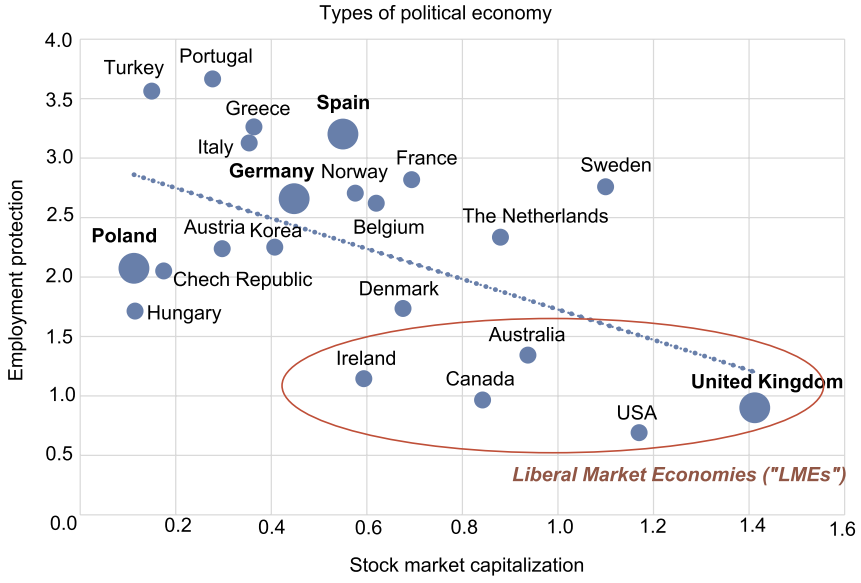

Fig. 9. Employment protection 1990–2005 from OECD Employment Outlook. Stock market capitalization of indigenous firms excluding mutual funds as a share of GDP, from OECD. Data from Tables in Schneider and Paunescu (2012), Annex 1.

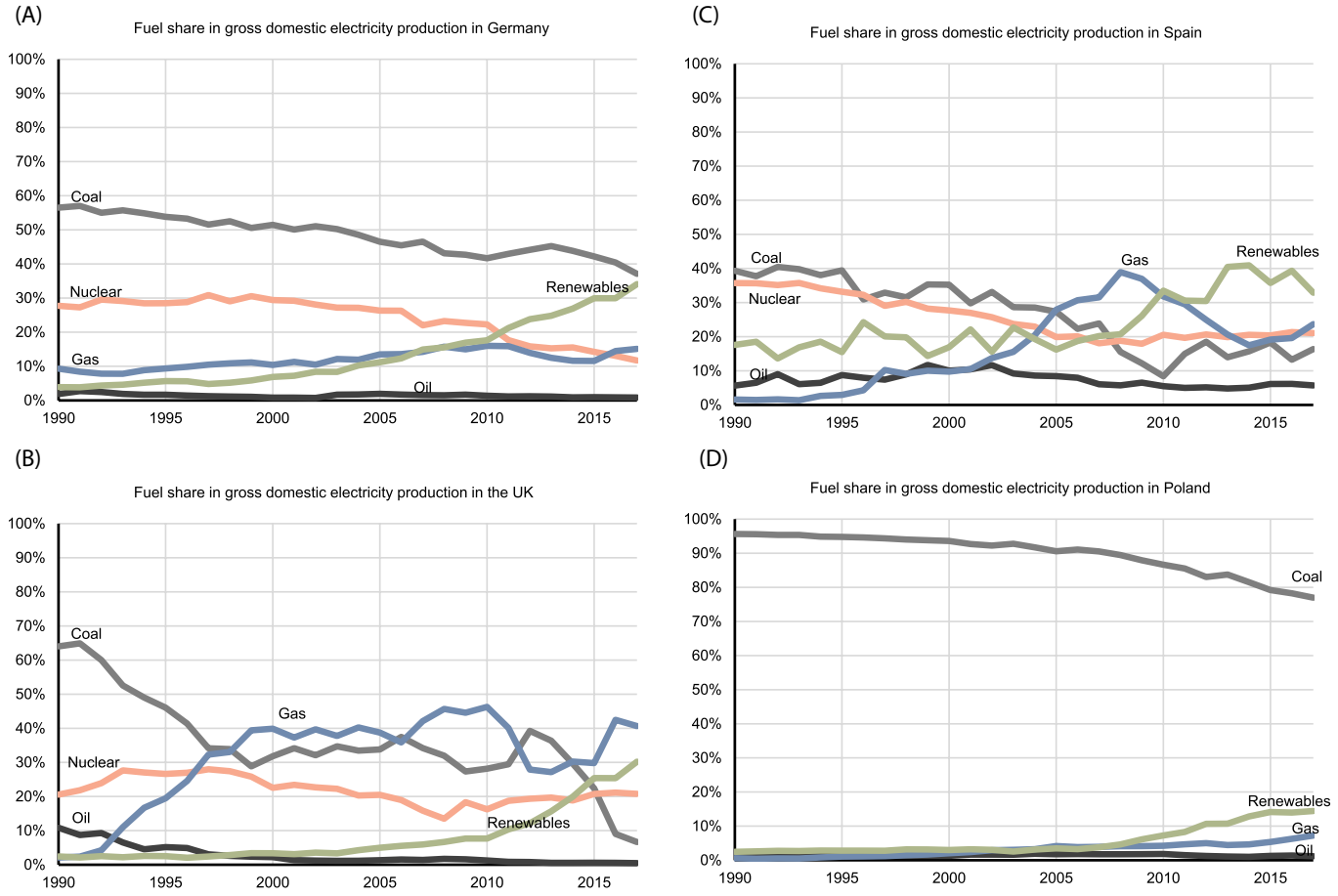

Fig. 10. (a)Share of fuels in gross electricity generation in Germany based on EC(2019). (b) Share of fuels in gross electricity generation in the UK based on EC(2019) (c) Share of fuels in gross electricity generation in Spain based on EC(2019) (d) Share of fuels in gross electricity generation in Poland based on EC(2019)

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