Do climate policies explain the productivity puzzle? Evidence from the Energy Sector

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Abstract

Productivity growth in advanced economies has slowed. What accounts for it remains a puzzle. One possible explanation lies with the increased stringency of environmental regulations. We investigate this possibility in the case of the regulated energy network industries in a sample of OECD countries over the period 1998-2016. Our analysis is twofold. First, using the growth accounting method, we estimate total factor productivity (TFP) growth in the electricity and gas sectors and find that these exhibit a lower TFP growth than the whole economy over the period. TFP growth falls further post-financial crisis. Second, we identify the impact of climate policies on productivity levels. We find that energy and climate policy indirectly reduced energy sector and economy-wide productivity.

1. Introduction

Increases in factor productivity are one of the most important sources of economic growth and rising living standards. Over the last three decades, productivity – total factor productivity (TFP) and labour productivity – in almost all advanced economies has been flatlining (and in some cases, falling), after experiencing a long period of steady growth. This trend has become more evident since the Global Financial Crisis of 2008 since when the TFP performance of many OECD countries has been extremely poor. For instance, the current productivity slowdown – even before the impact of COVID-19 – in the UK has led to the productivity level in 2018 being 19.7 per cent below the level it would have reached, had the pre-2008 trend path prevailed (Crafts and Mills, 2020). This is almost double the previous worst productivity shortfall a decade after the beginning of a recession.

Two early explanations for changes in productivity investigated by the literature were (i) the development and deployment of information and communication technologies (ICT) (see, e.g. Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000, Jorgenson et al. 2006, Corrado, et al., 2007), and (ii) the stringency of product market regulation and other competition enhancing policies (e.g., Nicoletti and Scarpetta, 2003).[2] More recently, several studies explored the impact of climate policies (primarily carbon pricing mechanisms) on productivity growth.[3] A common feature of these studies is their focus on market services and manufacturing industries.[4] Surprisingly, however, there has been no industry-level empirical study on the energy industries. Yet these

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[2] It could be that productivity growth was going to generally slow down as we hit diminishing returns to investment and hence there is no puzzle. However, our analysis goes beyond this by analysing the differential impacts of policies between countries.

[3] See Venmans et al. (2020) for a review of recent studies on the topic.

[4] Inklaar et al. (2008) focus on market services industries and find no effect of the average level of barriers to entry in services on productivity growth. The nonmanufacturing sector remains the most regulated and state-protected part of the OECD economy, while manufacturing industries have few visible restrictions to competition (Bourlès et al; 2013).

industries have also been the subject of similarly significant changes in their regulatory environment, over the same period, experienced a slowdown in aggregate productivity growth.

New or strengthened climate policies formed part of this change. For instance, at the core of the European Union's agenda is the decarbonisation of its economies, which has resulted in the formulation of legally binding greenhouse gas (GHG) emissions reduction targets for member states. To achieve these targets, the EU implemented market-based environmental policies such as the EU Emissions Trading System (ETS) to incentivise the deployment of renewable electricity generation capacity and improve energy efficiency. Consequently, this sector experienced upward cost pressures which could have affected its performance. Specifically, large amounts of capital have been invested into the energy sector at a time when demand has been falling.

We contribute to the literature by investigating the role of these regulatory changes in explaining the productivity slowdown, focusing specifically on the impact of climate policies on productivity in the electricity and gas sectors[5]. Our paper follows the renewed interest in the cause of the observed productivity puzzle and offers a twofold contribution. First, we examine the productivity trends in the electricity and gas sectors by taking advantage of the new EU KLEMS database which contains disaggregated energy sector data[6]. We explore the sector TFP growth trends, in a growth accounting framework, prior and after the global financial crisis, while comparing this trend to the TFP growth patterns of the total economy for OECD countries. We also evaluate the contribution of inputs (capital and labour) to the growth of valued added. Second, we focus on examining the relationship between the level of TFP in the electricity and gas sectors and the stringency of climate

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[5] Energy sector and electricity & gas sectors are used interchangeably throughout the paper.

[6] The latest release (November 2019) of the EU KLEMS database run by the Vienna Institute for International Economic Studies (wiiw) contains data for the energy sector (electricity and gas) reported under code D. The previous EU KLEMS database releases (up to the 2018) have always aggregated data for the utilities sector (electricity, gas and water) and reported them together under code D-E. For the new EU KLEMS data release, see www. euklems.eu.

policies. We analyse separately the impact of two types of climate policies: carbon pricing mechanisms and feed-in-tariffs for renewable energy. To our knowledge, this is the first attempt at identifying the relationship between climate policies and the level of TFP either at the economy level or in the energy sector.

Our findings confirm that a productivity puzzle does exist in the energy sector and in aggregate TFP growth, and we shed new light on the extent to which TFP levels in aggregate and in the energy sector are being held back by climate policy. Somewhat unsurprisingly, the productivity puzzle at the whole economy level in OECD countries would seem to at least be partly due to more ambitious climate policy.

The remainder of the paper is structured as follows. Section 2 presents the literature review and Section 3 sets out the methodologies used in the paper. Section 4 describes the data we use and Section 5 discusses our results. Section 6 provides some conclusions and suggestions for further work.

2. Literature

The existing literature in the growth accounting framework has provided numerous empirical studies which attempt to identify the contribution of inputs and productivity to the change in the growth performance in advanced economies. Much research based on growth accounting has stressed that investment in ICT explain the United States growth surge (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000; Ferguson and Wascher, 2004; Jorgenson et al. 2006 and Corrado, et al., 2007). Far smaller productivity gains from ICT investment account for the lagging productivity in Europe, ostensibly due to the insufficient investment in ICT capital (Daveri, 2002;

van Ark et al., 2002; Albers and Vijselaar, 2002 and van Ark and Jäger, 2017). Studies such as Gust and Marquez (2002) reveal that TFP growth decelerated in most European countries as well as in Japan but that the United States, Finland, Sweden, Australia, and Canada experienced a positive TFP growth from 1995-2000. Exploring the productivity gap between Europe and the United States, van Ark, et al. (2008) show that productivity growth in the United States accelerated from 1.2 percent in the 1973–1995 period to 2.3 percent from 1995 to 2006 while the continental European Union countries experienced a productivity growth slowdown from an annual rate of 2.4 percent to 1.5 percent between these two time periods. Although differences in total input factors growth have been proposed to account for these divergent trend growth rates, most studies suggest that productivity differences explain a larger share of per capita income differences across countries than differences in input accumulation.

The steady strengthening of climate change mitigation policies observed over the last quarter century constitutes a source of significant alteration to firms' and sectors' regulatory environment, which may be partly responsible for the evolution of TFP.[7] Due to the nature of their activity, network industries have been particularly exposed to these changes, having had to comply with a growing number of environmental regulations (Botta and Kozluk, 2014). While these were initially focused on the protection of the local environment, such as in the case of the U.S. SO_2 (Sulfur Dioxide) Program, recent years have witnessed the implementation and strengthening of legislation aiming at regulating global pollutants. Many OECD countries have introduced economy-wide or, more often, sector-level climate policies whose scope encompass the electricity and gas industries. In most countries, the electricity sector was among the first sectors to face

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[7] Such changes affect firms' production processes, resource reallocation, capital investment, labour intensity and innovation incentives (Albrizio et al., 2017). This, in turn, has the potential to affect the performance of firms, sectors, and economies.

climate change mitigation regulations.[8] Hence some of these regulations (e.g., carbon pricing and feed-in-tariffs) have now been in place for some time, allowing for an evaluation of their impact on the economy and the energy sector.

Much of the debate about the relationship between environmental regulation and firm performance dates back to the seminal work of Porter (1991). Although *Porter's hypothesis* merely suggested a relationship between environmental regulation and firm-level innovation, later work has described its potential implications for firm performance. Palmer et al. (1995) and Jaffe and Palmer (1997) were among the first to describe such implications. They identify two interpretations of the hypothesis with opposite implications for firm performance. Under one interpretation ('*weak*'), environmental regulations impose additional constraints on firms' optimization problem and hence are expected to weigh negatively on their performance but hold the potential to stimulate certain kinds of innovation.[9] Under an alternative interpretation (*'strong'*), the introduction of new (and sometimes unexpected) environmental regulation constitutes a shock that prompts firms to exploit previously unexploited profit opportunities while complying with the regulation. In this case, one expects environmental regulation to result in an improvement in firm performance.

Porter's initial suggestion and subsequent discussions about its implications for firm innovation and performance stimulated substantial empirical work seeking to discuss it in a variety of institutional contexts. Studies investigating the 'strong' hypothesis focused on productivity (growth) whereas those exploring the weak hypothesis focused on innovation. Early studies focused primarily on the effect of local pollutant regulations, reflecting the policy developments

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[8] These policies were gradually extended/introduced in new sectors. For an up-to-date review of existing Renewable Energy Targets and Policies, see REN21 (2021). A more historical perspective is provided by the Climate Policy Database of the New Climate Institute, http://climatepolicydatabase.org/index.php/Climate_Policy_Database.

[9] As noted by Jaffe and Palmer (1997) themselves, this applies to firms that do not have a comparative advantage in environmental compliance or firms that invested in pollution abatement technologies prior to the introduction of environmental regulation. Such firms would most likely benefit from the regulatory change.

of the time (Cohen and Tubb, 2015; Kozluk and Zipperer, 2014; Ambec et al., 2013). Most of these studies used sector-level data and, except for Albrizio et al. (2017), were focused on single context and have reached opposing conclusions.[10] That is, the evidence available from it does not allow to draw a conclusion as to the significance and direction of the effect of environmental regulation on firm productivity (growth). As noted in Ellis, Venmans et al. (2019), more recent studies have attempted to identify the effect of some climate policies on a number of firm/sector performance indicators. Among them, several focused on the relationship between carbon pricing and total factor productivity (Calligaris et al., 2018; Lundgren, 2015) in manufacturing sectors.

None of these studies, however, focused on the energy sector and virtually all of them investigated the role of the EU-ETS, with only one, Commins et al. (2015), focusing on carbon taxes. Yet one might expect that the energy sector itself is more likely to exhibit the 'weak' rather than the 'strong' Porter hypothesis given that increasingly stringent environmental regulations – especially with respect to measures to reduce energy consumption/output – have been directly applied to it. Energy sectors are likely to have more limited growth opportunities than non-energy sectors subject to environmental regulations.

One study to date, Albrizio et al. (2017), has included a wider range of climate policies in the scope of its investigation, using an environmental policy stringency index constructed by Botta and Kozluk (2014). In doing so, it attempts to get around the constraint posed by the lack of standardised cross-country proxies for the climate policies introduced. However, the focus is on overall policy stringency, which includes policies aimed at reducing emissions of both local and

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[10] See Albrizio et al. (2017) for a review of these studies.

global pollutants and encompasses market and non-market-based policies. In other words, their study does not allow the disentangling of the effect of climate policies specifically.

This paper adds to earlier literature in three ways. First, its time coverage extends to years following the global financial crisis, when the productivity puzzle is particularly apparent not only in Europe but across all developed economies. Second, it focuses specifically on a regulated sector, the energy sector. Most studies so far have focused on multi-industry analysis, especially covering the manufacturing sector, which uses intermediate inputs from the regulated industries, and have generally attributed the slowdown in productivity to insufficient investment in ICT and document negative impact of regulation on TFP in the sector. Finally, this paper presents a first attempt at investigating the effect of climate policies on the productivity level of the energy sector.

3. Methodology

We follow the standard growth accounting method, which explains the growth of outputs (i.e., GDP, value added - VA) by the growth of a number of inputs (such as labour, capital and intermediate inputs) and by an unaccounted or unexplained factor, the growth residual[11], which represents productivity growth. Theories about growth accounting methods and applications have evolved over time with some key influential studies from Abramovitz (1956), Solow (1957), Kendrick (1961), Jorgenson and Griliches (1967) and Jorgenson et al. (1987).

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[11] This is also referred as a measure of “ignorance”, Abramovitz (1956).

The methodology we use for estimating the TFP growth figures is based on Jorgenson et al. (1987), in line with the one used by EU KLEMS[12] project (Timmer et al., 2007, Stehrer, et al., 2019). The production function for industry *i* can be written as follows:

$$Y_i = fi\ (Ki, Li, Mi, T) \tag{1}$$

Where Y is output, K is capital services, L is labour services, M is intermediate inputs (purchases from other industries), T accounts for technology indexed by time. Based on the assumption of constant return to scale and competitive markets[13], the growth of industry level can be expressed as[14]:

$$\Delta lnY_t = \tilde{v}^M \Delta lnM + \tilde{v}^K \Delta lnK + \tilde{v}^L \Delta lnL + \Delta lnA \tag{2}$$

Where Δ denotes changes between periods $(t, t+1)$, ṽ represents two period average of the share of the input related to the nominal value of output given by Eq. 3, and *A* the TFP.

$$v^M = \frac{P^M M}{P^y Y}; \quad v^L = \frac{P^L L}{P^y Y}; \quad v^K = \frac{P^K K}{P^y Y} \tag{3}$$

In addition, the assumption of constant return to scale means that $v^M + v^L + v^K = 1$ which allows the estimation of TFP growth (ΔlnA) based on the share of the observed inputs.

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[12] EU KLEMS stands EU level analysis for capital (K), labour (L), energy (E), materials (M) and service (S) and the, and the US. For the latest update of the EU KLEMS data, see www. euklems.eu.

[13] This means that the value of output is equal to the values of all inputs then $P^Y Y = P^K K + P^L L$, where P^Y, P^K, P^L denote the prices of output, capital and labour.

[14] The decomposition made in Equation 2 is the basis of growth accounting results in the EU KLEMS database.

The component ΔlnY_t from Equation 2 denotes growth in output. However, a narrower measure, value added (VA), can be estimated using the same equation. In this case, only capital and labour are considered as inputs to production[15]. Based on Equation 1, value added can be represented as follows:

$$VA_{i\,=}\; f^{i}\,(K_i, L_i, T) \tag{4}$$

Then in agreement with Equation 2, Equation 4 can be denoted as follows:

$$\Delta lnVA_t = \bar{e}^K \Delta lnK + \bar{e}^L \Delta lnL + \Delta lnA \tag{5}$$

$$\text{Where}\;\; \bar{e}^L = \frac{P^L L}{P^{va} VA}\;,\; \bar{e}^K = \frac{P^K K}{P^{va} VA} \tag{6}$$

Applying the constant return to scale which means that $\bar{e}^K + \bar{e}^L = 1$, Equation 5 can be written as:

$$\Delta lnVA_t = \bar{e}^K \Delta lnK + (1 - \bar{e}^K)\Delta lnL + \Delta lnA \tag{7}$$

The TFP growth estimations and discussion in this study are based on value added instead of gross output, which means that intermediate inputs have been excluded from the TFP analysis[16]. Results from the two methods are different[17], and those results from value added TFP growth are usually

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[15] This is explained by the fact that $Gross\ Ouput\ (GO) = Value\ Added\ (VA) + Intermediate\ Inputs\ (II)$. Then the component that reflects the share of intermediate inputs in Equation 2 is not included.

[16] One of the main reasons for this is the lack of information of GO variables from the latest EU KLEMS data base.

[17] According to Cobbold (2003, p.23): *"The gross output method is intended to measure disembodied technological change whereas the value-added based measure reflects an industry's capacity to translate technical change into income and into a contribution*".

higher than those from gross output based TFP growth (van der Wiel, 1999, Oulton, 2000). Both methods have pros and cons and the selection of one or another method may depend on the purpose of the productivity measure (OECD, 2001).

In the second empirical section of this study, we relate productivity growth (calculated from productivity levels estimated using our growth accounting framework) to likely determinants of productivity. Using a panel approach, we first regress total factor productivity on market regulation indicators and a set of macro variables which capture some cross-country differences in the second analysis. We then specify the same model for relationship between productivity and a set of climate policies. To mitigate the potential endogeneity problems, we lag all explanatory variables one year, which we do throughout our regressions for all variables[18]. The structure of the estimated equations is thus:

$$Y_{it} = \beta Z_{it-1} + \gamma X_{it-1} + \eta_{it} + \psi_{it} + \varepsilon_{it} \tag{8}$$

where Y_{it} is total factor productivity level of country i, in year t, Z_{it-1} denotes either product market regulatory indicators measured by the OECD regulatory index (aggregate index, entry barriers, public ownership, vertical integration, market structure) or proxies for the stringency of climate policies. X_{it-1} is vector of country-specific macro variables (GDP per capita, energy consumption, energy import and renewable capacity), η_{it} is unobserved time-invariant country-specific fixed effects, ψ_{it} is time fixed effect and ε_{it} is the idiosyncratic error term.

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[18] This approach is a based on the assumption that the lagged values of the policy are uncorrelated with the error terms of the regression equation. For application of this approach on TFP growth analysis, see Buccirossi et al., 2013; Bourlès, et al., 2013; Duso et al., 2019 and Griffith et al., 2004.

4. Data description

Three sets of data are used. The first dataset comes from the new EU KLEMS Growth and Productivity Accounts based on the November 2019 release of the EU KLEMS database. This database is maintained by the Vienna Institute for International Economic Studies (wiiw) which incorporates the latest EU KLEMS update. The latest database series covers measures of output, inputs and TFP growth at the industry level for all European Union member states, Japan and the United States. The statistical database component contains growth accounts and national accounts files. To build a sector level dataset for our study, we consider network industries - i.e. electricity & gas - and total economy for the period 1998-2016 across 22 countries[19]. The growth accounts file of the EU KLEMS database offers information in percentage points about TFP growth and also contains more granular industry-level measures of the growth of skill distribution of the labour force and a detailed capital input growth decomposition. Labour input growth reflects not only changes in hours worked, but also changes in labour composition in terms of the effort and skills of the workforce across time. Capital input growth is decomposed into five components of which two are tangible capital services — tangible ICT capital and tangible non-ICT capital—and three are intangible capital services— intangible research & development (R&D), intangible software and database (SoftDB) and intangible other intellectual property products (OIPP).

Second, we obtained data on industry-specific real capital stock, proxied by real gross fixed capital formation, expressed in national currencies at 2010 prices and publicly available in the capital data file of the EU KLEMS database to estimate TFP using production function approach proposed by

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[19] Due to the limited times series of the growth accounting data for some countries, we only focus on 13 countries which have sufficient data that allows for meaningful comparison across the pre-and- post financial crisis period. The 13 countries considered in the growth accounting section of the study are Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Netherland, Sweden, United Kingdom and United States.

Levisohn and Petrin (2003). Data on gross value added, labour and material, proxied by intermediate input, are sourced from the national accounts file of the EU KLEMS database. Labour is expressed in thousand number of persons employed, gross value added and material are expressed in millions of national currencies at current prices and are deflated using the corresponding sectors price index of gross value added (2010 = 100). The real gross value added, real capital stock and real material in national currencies are then converted to dollars (US$) using the exchange rate from the Penn World Tables (PWT9.1). Besides the regulatory variables and the standard variables of TFP level production function estimation, we added macro variables to account for institutional differences across these sample countries. These variables are GDP per capita obtained from the World Bank as well as electricity consumption, energy import as a share of total energy consumption and net renewable total capacity – provided by the International Energy Agency (IEA) through the UK data service (IEA, 2019a, 2019b, 2019c).

Finally, we include variables capturing the stringency of two types of climate policies: carbon pricing and Feed-in-Tariffs (FiTs). The sector-level carbon price data used in the models estimated below is constructed based on a dataset of sector-fuel level carbon prices (see Dolphin et al., 2020). The energy industry carbon prices are constructed as emissions-weighted averages of these sector-fuel level carbon prices and expressed in 2019USD/tCO2e. This approach follows the methodology described in Dolphin et al. (2020). Three different carbon price variables are used. These allow to distinguish between the carbon price arising from (i) carbon taxes, (ii) emissions trading systems, or (iii) both. As a result, we are able to discuss the impact on productivity of all carbon pricing instruments as well as each type of pricing instrument individually.[20] The stringency of Feed-in-Tariff policies is captured by stringency indices provided by the OECD (see

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[20] For a discussion as to why a distinction between these instruments might be warranted, see Section 5.2.

Botta and Kozluk, 2014). Model estimates are based on data for all 22 countries.

5. Results

5.1 Growth accounting analysis

To provide context to estimates of total factor productivity (TFP) growth in the electricity and gas sector, we contrast these with estimates of TFP for the total economy. The analytical period spans 1998-2016 across 13 sample countries using the growth accounting data from the EU KLEMS database[21]. Figure 1 shows TFP growth, which reflects the portion of gross value-added growth not attributed to inputs, for all countries over the sample period. With the exception of Italy, TFP growth contributed positively to the growth of value added of the total economy during this period[22]. However, the electricity and gas sectors experienced substantial negative TFP growth, particularly in countries such as Japan, the United Kingdom, Italy, Sweden, Czech Republic, United States, France and Finland. Countries such as Germany, the Netherlands, Denmark, Austria and Belgium, on the contrary, witnessed a positive TFP growth during the period. Overall, Germany experienced the largest average growth rates in electricity and gas sectors (1.1% p.a.), while Japan recorded the least productivity growth of -6.1% p.a. The Czech Republic has the highest average productivity growth in the total economy (1.3% p.a.).

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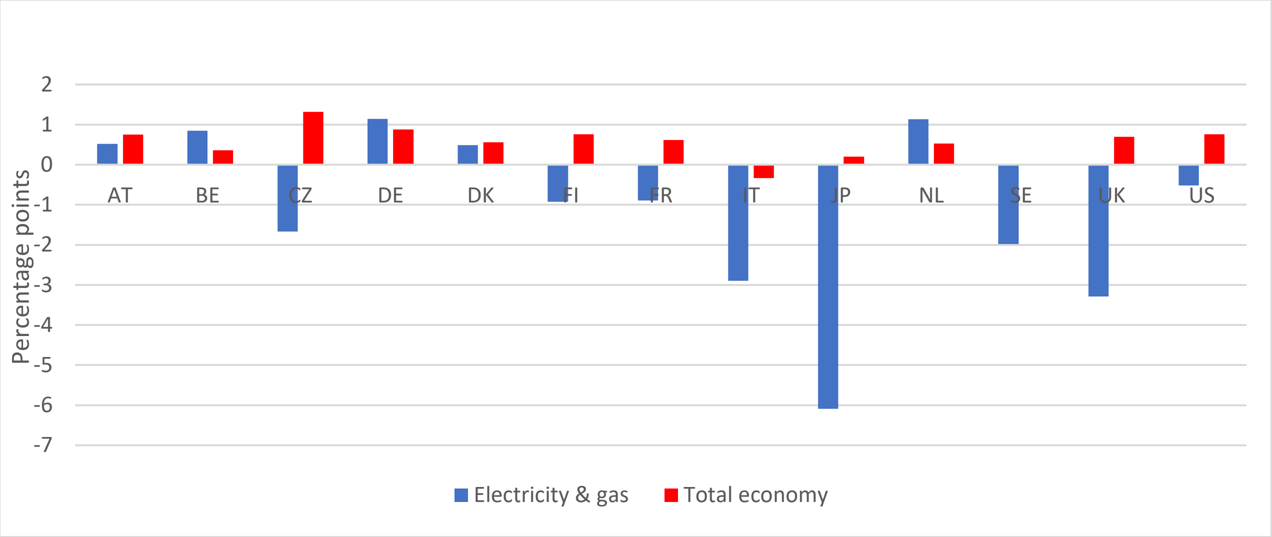
[21] We annualized data to account for the fact that years of data coverage differ across countries. For example, there is no data for Japan in 2016.

[22] The value of TFP growth for total economy for Sweden is near zero.

Figure 1: Total Factor Productivity Growth, p.a., 1998-2016



Source: EU KLEMS DATABASE, 2019.

We disentangle the TFP growth results into two time periods (1998-2007 and 2008-2016) as shown in Figure 2, in order to gain more insights into the structural break occasioned by the global financial crisis on total factor productivity growth. There appears to be a substantial difference in TFP growth among countries before and after the global financial crisis. Looking at the TFP growth in the electricity and gas sectors, the negative TFP growth of Japan is particularly striking as the country experienced the largest negative growth in TFP growth among the sample countries, averaging -13.7% p.a., in the period after the crisis despite maintaining a near-zero TFP growth before the crisis. This dismal TFP growth performance in the Japanese electricity and gas sector is not surprising in light of the earthquake at the Fukushima Daiichi power plant in March 2011, which led to the closure of many nuclear plants and resulted in a considerable loss of electricity production, physical and human capital (Rafindadi and Ozturk, 2016). This event singlehandedly caused a steep TFP decline in the electricity and gas sector amounting to an annual productivity growth of -30% p.a. and -61% p.a. in 2011 and 2012 respectively[23].

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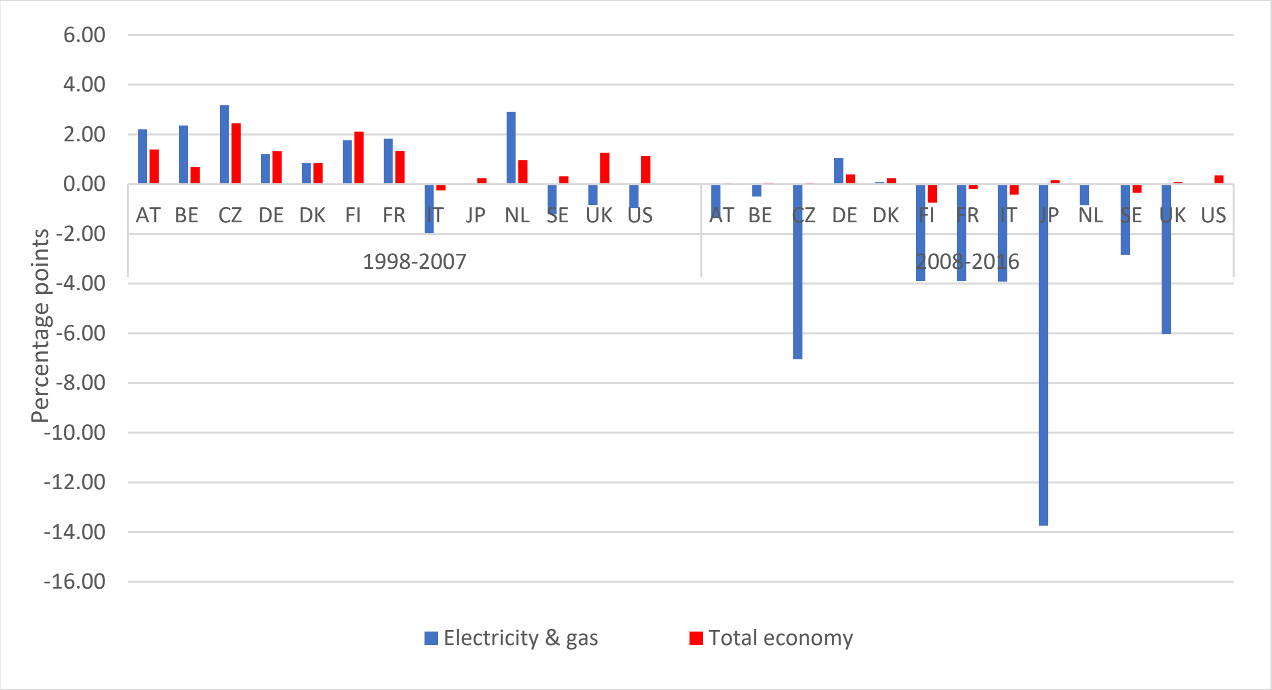
[23] See Figure A1 in the Appendix for TFP growth by country across years in the electricity and gas sector.

Figure 2: Total Factor Productivity Growth p.a., Pre and Post Financial Crisis



Source: EU KLEMS DATABASE, 2019.

In the UK, TFP growth in the electricity and gas sector has been lacklustre with an average annual TFP growth of -0.8% p.a. observed before the 2008 crisis. The average annual negative productivity growth widened amid tepid productivity performance following the crisis, amounting to -6.0% p.a. in the electricity and gas sectors. It is also interesting to note that Italy recorded the largest negative growth in TFP of about -1.97% p.a. before the crisis, a trend exacerbated after the crisis and yielding an average TFP growth rate of -3.92% p.a. This is consistent with Morsy and Sgherri (2010) who posit that the financial crisis was expected to have a long-lasting impact on Italy's economy and the negative TFP growth trajectory was highlighted to have been caused by resource misallocation (Hassan and Ottaviano, 2013).

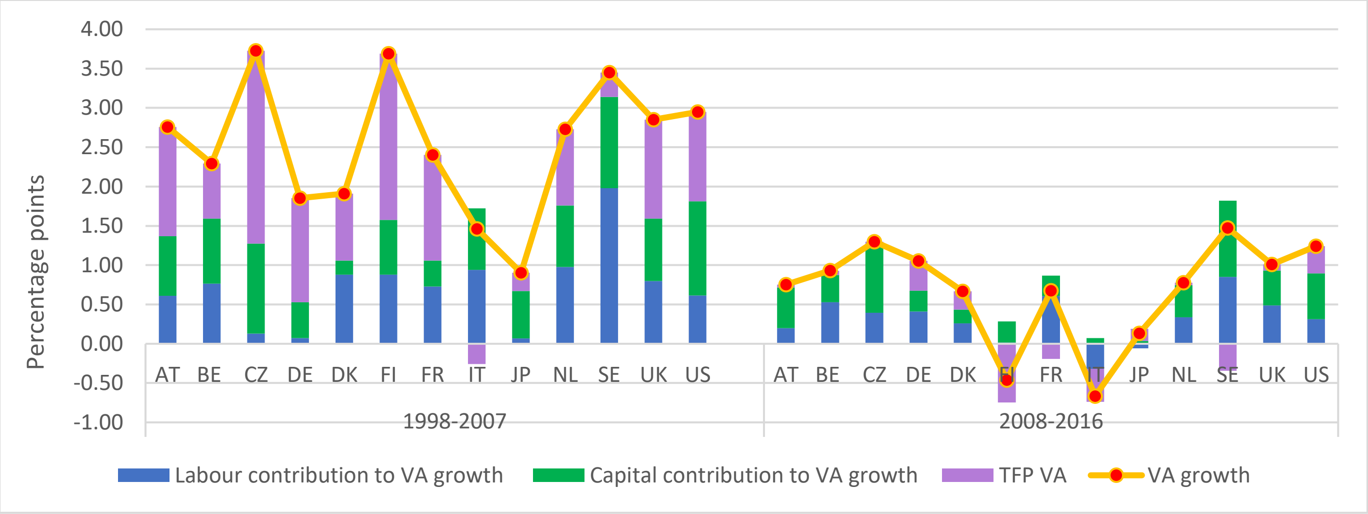
In the case of France, a positive average annual TFP growth was observed before the crisis in the electricity and gas sectors, as well as for the total economy. However, this trend turned negative after the crisis, with the electricity and gas sectors experiencing the highest productivity decline (-3.9% p.a.). This post-crisis development in the electricity and gas sectors is also true for most European countries, e.g. Finland (-3.9% p.a.), with a much stronger decline for Czech Republic (-7.4% p.a.), and a moderate decline for Sweden (-2.8% p.a.), Austria (-1.5% p.a.), The Netherlands (-0.9% p.a.) and Belgium (-0.5% p.a.). On the contrary, only Germany maintained an appreciable positive TFP growth of after the crisis (1.1% p.a. on average) in its electricity and gas sector, although the productivity growth was marginally lower than its pre-crisis growth of 1.2% p.a.

Despite the 2001 dotcom crisis and the financial crisis in 2008, the United States did not experience a negative productivity growth in the total economy in the two time periods. However, the productivity growth of the electricity and gas sectors was negative (-0.96% p.a.), perhaps due to the mix of factors such as higher prices in restructured states (Borenstein and Bushnell, 2015) and California's electricity crisis (Kwoka, 2008) that brought about the suspension of further electricity restructuring that could have enhanced efficiency in the sector in most states. Of course, the later period saw a moderate improvement in the sectors with an average annual productivity growth of 0.02% p.a, arguably due to improved drilling techniques and increased well productivity in shale gas production (see Ikonnikova and Gülen, 2015; Montgomery and O’Sullivan, 2017).

The sources of the post-crisis slowdown in global value-added growth have been the subject of debate, with mainly two lines of argument put forward to explain this development. The first one is that it is traceable to a notable shortfall in capital investment, the second points to the flattening productivity levels witnessed currently. Thus, decomposing the growth rate of valued added into its different components can shed on this debate. We decompose value added growth into TFP growth, labour input growth and capital input growth and highlight the relative contribution of each component to value added growth.

Figures 3a and 3b plot the growth contributions of factor inputs and TFP to value added growth for the total economy and electricity & gas sectors respectively. A cursory look at the figures shows that TFP growth is the major driver of slower growth in the post-crisis period. For the economy as a whole, Figure 3a shows that while Germany growth of value added slowed from 1.9% p.a. on average per year in the period 1998-2007 to 1.1% p.a. in the period 2008-2016, the UK growth slowed substantially more from 2.9% p.a. in the period 1998-2007 to only 1.0% p.a. in the period. Nevertheless, capital input growth has remained a positive driver of growth in both periods for almost all countries in the sample. This is especially the case in the United Kingdom and Sweden. On the contrary, rapid TFP growth in the pre-crisis period was significantly reduced in the post crisis period, explaining most of the weak total economy value added growth in this period. Thus, given the tanking global macroeconomic growth, the rapid slowdown the TFP growth represents a serious concern to the electricity and gas sector, and total economy of the sample countries.

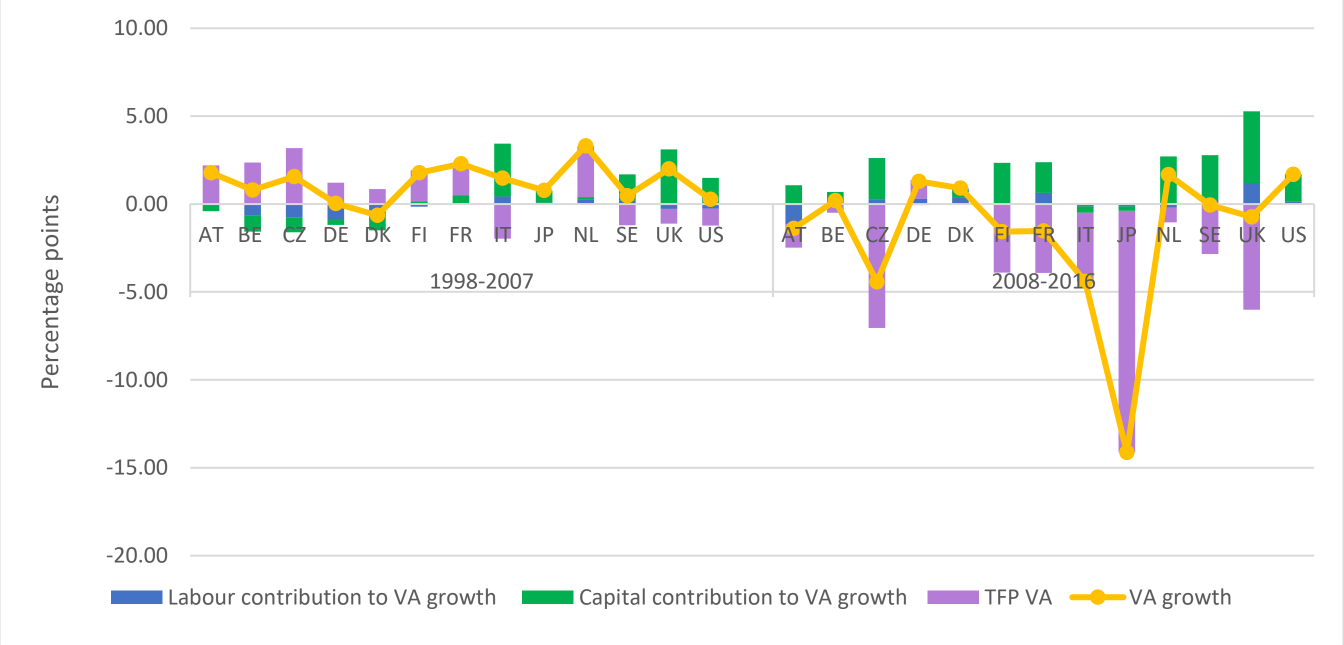
Figure 3a: Contributions to annual Growth of Value Added in Total Economy



Source: EU KLEMS DATABASE, 2019.

In the case of the electricity and gas sectors as shown in Figure 3b, the growth rate of value added fell markedly in the period following the financial crisis, driven mainly by dwindling productivity growth, with an abrupt dip in Japan. While the share of capital input growth in the value-added growth increased significantly in post-crisis period, especially in the United Kingdom, Finland, France and the Netherlands, it is surprising to observe that the accumulation of capital input could not offset the negative trajectory in value added growth. For instance, whereas capital growth in the United Kingdom increased by almost a full percentage point from 3.1% p.a. from 1998-2007 to 4.1% p.a. from 2008-2016, the valued added growth declined from 2% to 0.7% between these two periods. In addition, a substantial rebound (relative to pre-crisis) in value added growth was recorded in Germany, Denmark and United States. However, annual productivity growth in these countries over the 2008-2016 period was of 1.3% p.a., 0.9% p.a. and 1.3% p.a. respectively.

Figure 3b: Contributions to Growth of Value Added in Electricity & Gas sectors



Source: EU KLEMS DATABASE, 2019.

The slowdown in TFP growth in the electricity and gas sectors might be caused by a number of factors, many of them attributable to a set of global agreements and regional (European) directives (and ensuing national legislation to meet the objectives of these directives). For example, the Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and the Renewable Energy 2018/2001/EU directives prompted the 2050 decarbonisation targets by the UK government, which set a long-term GHG reduction target of 80% by 2050 compared to 1990 levels[24]. This has important implications for productivity growth as these policies promote resource use efficiency and electricity generation by low carbon technologies. More specifically, the national energy sector reforms ensuing from EU regulations might be associated with substantial increases in capital cost due to the addition of renewables and increased interconnection and lower demand as a result of increased energy efficiency (which itself might add capital costs). Meanwhile increased renewable generation displaces fossil fuel plants and lowers wholesale prices. This implies higher input costs at time of lower revenues and hence lower measured TFP growth.

5.1.1 Simple correlation

The results of the above analysis show important variation in the contribution of growth in factor inputs and TFP to value added growth. We carry out a pairwise correlation analysis to investigate the degree of variation of these growth contributions. The correlation between output growth, factor inputs growth and productivity growth for the total economy is reported in Table 1. Both TFP and labour input growth have a positive and statistically significant correlation with value added growth, at 0.87 and 0.69 respectively, while capital input growth is fairly correlated with

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[24] For a discussion on UK decarbonisation pathways, See Pye et al. (2015).

value added growth at about 0.4. The correlation coefficient of TFP growth reinforces our earlier findings that TFP growth is the major driver of value-added growth. Thus, it appears that countries with low value-added growth are associated with a lower TFP growth in the whole sample period.

Table 1: Growth of Inputs, TFP & VA correlation for total economy p.a., 1998-2016

	TFP growth	Labour input growth	Capital input growth	Value added growth
TFP growth	1			
Labour input growth	0.2923***	1		
Capital input growth	0.1233*	0.3300***	1	
Value added growth	0.8737***	0.6882***	0.3965***	1

Table 2 reports the correlation of growth contributions in the electricity and gas sectors. We observe that annual TFP growth is also highly correlated with valued added growth. However, labour input growth and capital input growth are not significantly correlated with value added growth. Strikingly, the findings reveal another difference in the correlation between TFP growth and factor input growth: while TFP growth is negatively correlated with capital and labour input growth in electricity and gas sectors, the correlation of TFP growth with input growth is positive in the total economy. These correlations are reassuring in that the whole economy behaves as we might expect while electricity and gas sectors are different.

Table 2: Growth Inputs, TFP & VA correlation for electricity and gas sectors, 1998-2016

	TFP growth	Labour input growth	Capital input growth	Value added growth
TFP growth	1			
Labour input growth	-0.2218***	1		
Capital input growth	-0.2312***	0.1487**	1	
Value added growth	0.9601***	-0.0440	0.0074	1

Finally, Table 3 reports the correlation of TFP growth among electricity & gas sector, and total economy. It shows that electricity and gas sector TFP growth has a weak but significant correlation with the total economy's TFP growth, underscoring the supposition that productivity growth in the electricity & gas sector tends to behave differently from the total economy.

Table 3: Electricity & Gas, and Total economy TFP growth p.a. correlation, 1998-2016

	Electricity & Gas	*Total economy*
Electricity & Gas	1	
Total economy	0.1817***	1

To further illustrate the TFP growth slowdown arising post-global financial crisis, we turn to price data in order to examine whether it is driven by a price effect. That is, if the change in price index as observed in the implicit price deflator measured in national currencies reflects any increase in productivity growth, as well as in value added growth. Looking at the correlation results, Tables 4-5 show that the price index growth is inversely correlated with productivity growth for the electricity and gas sectors, and the total economy. This negative relationship is also present in the correlation between the price index growth and the growth rate of value added. This is interesting as it suggests that a decrease in price occasioned by falling costs of inputs is associated with increasing productivity growth in the electricity and gas sectors, and total economy.

Table 4: TFP, Value Added & Price Indices Correlation- Total Economy p.a., 1998-2016

	TFP growth	*Growth rate of value added*	*Price_Index growth*
TFP growth	1		
Growth rate of value added	0.8737***	1	
Price Index growth	-0.2247***	-0.3257***	1

Table 5: TFP, Value Added & Price Indices Correlation- Electricity & Gas Sector p.a., 1998-2016

	TFP growth	*Growth rate of value added*	*Price_Index growth*
TFP growth	1		
Growth rate of value added	0.9601***	1	
Price Index growth	-0.2514***	-0.2116***	1

The extent of the contribution of different dimensions of capital such as tangible assets (ICT capital and non-ICT capital) and intangible (R&D, software and database and other intellectual property products) to capital input growth was also examined, see Tables A1 and A2 in the Appendix. Table A1 shows that all capital input components i.e., both tangible and intangible capital are significantly associated with capital input growth in the total economy. Table A2 reports that only tangible capital input growth is positively and significantly associated with overall capital input growth, while intangible capital growth is not significantly correlated with overall capital input growth in electricity and gas sector[25].

Furthermore, we attempt to examine the past behavioural patterns of factor input growth and TFP growth in relation to gross value-added growth by looking at historical data, especially the period that is not covered by our sample. Although, Tenreyro (2018) argues that the productivity growth slowdown seems be more pronounced in the UK following the post-crisis period relative to what has been experienced by other developed countries, much less emphasized is whether this experience is symptomatic of the past growth contribution or due to quality of factor inputs. Hence, we delink the growth contributions to value added growth in the total economy by splitting our data into pre-sample and sample period using the UK time series from 1970 to 2016. In the pre-sample period between 1970 and 1997, Table 6 reports the correlation results which show a

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[25] Tables A1-A3 are reported in the appendix

positive relationship between TFP growth and value-added growth while capital input growth has no significant relationship with value added growth.

Table 6: UK Market Sector Correlation, Pre-Sample Period 1970-1998, annual figures

	TFP growth	Labour contribution	Capital Contribution	Value added growth
TFP growth	1			
Labour contribution	0.1212	1		
Capital Contribution	-0.3805*	0.2001	1	
Value added growth	0.7667***	0.7207***	-0.0366	1

However, in the sample period between 1998 and 2016, Table 7 reports the correlation results which confirm a significant positive relationship between value added growth with capital input growth, albeit with a stronger positive relationship with TFP growth. Thus, the contemporary period points to an increasing role of capital deepening as a significant source of the valued added growth relative to the pre-sample period. This finding reinforces the UK productivity puzzle narrative that even though the U.K. economy was building sufficient intangible capital post-2000, the slowdown in aggregate economy productivity gains still remains (Marrano et al., 2009).

Table 7: UK Market Sector Correlation, Sample Period 1998-2016, annual figures

	TFP growth	Labour contribution	Capital Contribution	Value added growth
TFP growth	1			
Labour contribution	0.3464	1		
Capital Contribution	0.4225*	0.0662	1	
Value added growth	0.9210***	0.6435***	0.5211**	1

5.2 *Climate policy and productivity*

We now turn our attention to the effect of carbon pricing mechanisms and feed-in-tariffs on TFP level. We estimate a standard OLS (panel) model. The model includes both panel unit and time fixed effects, accounting for unobserved unit-specific/time-invariant and year-specific/unitinvariant effects, respectively. The number of observations available for each estimation is constrained by the observations available for either the productivity or policy variables. The carbon pricing series are available through 2016 for all 22 panel countries while the feed-in tariffs stringency variables are available through 2012 for 20 countries.[26] The panels are unbalanced.[27] The analysis is conducted at the level of the economy (Table 8) and the energy sector (Table 9).

Three different carbon price variables are used, which allow to distinguish between the effects of carbon prices arising from (i) carbon taxes, (ii) emissions trading systems, or (iii) both. Although both instruments create an explicit price on emissions, their nature differs, and agents might react differently to them. For instance, Li et al. (2014) provide evidence that consumers respond more strongly to changes in gasoline taxes than changes in gasoline prices. One explanation they suggest is that they perceive a tax change as more stable than variation in fuel prices. Hence, it might be the case that they also respond differently to carbon prices arising from emissions trading systems than carbon taxes.

Several observations can be made. First, results suggest that carbon pricing mechanisms as a whole (tax and ETS together) had a substantial negative impact on an economy's aggregate TFP (Table 8, column 1). For every $1 increase in the average, economy-wide, price of carbon, the TFP decreases by 0.3%. However, interestingly, subsequent estimations at the economy level (columns 2 and 3) analysing the separate effects of carbon taxes and ETS suggest that this effect is mostly driven by the countries that introduced carbon taxes. These estimations show that the latter exhibits almost no effect on TFP while the effect of the former is statistically different from 0 and of a magnitude close to that estimated in column 1. In our sample, Finland, Norway, Sweden, Denmark,

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[26] Data for Estonia and Luxembourg are unavailable. Note that stringency variables are available through 2015 for some panel units.

[27] Some TFP observations are missing in some years of the sample for Estonia (1998-1999), Japan (2016).

Slovenia, Estonia, Japan, France introduced and maintained a carbon tax scheme in place throughout all years in the sample.

Table 8 – Effect of climate policies on total economy productivity

	lnTFP (1)	lnTFP (2)	lnTFP (3)	lnTFP (4)	lnTFP (5)
ETS+Tax $_{t-1}$	-0.003***				
	(0.001)				
Tax rate $_{t-1}$		-0.003***			
		(0.001)			
ETS price $_{t-1}$			0.0006		
			(0.002)		
FiT wind $_{t-1}$				0.004	
				(0.003)	
FiT Solar $_{t-1}$					0.004
					(0.003)
GDP per capita$_{t-1}$	0.6***	0.589***	0.57***	0.644***	0.671***
	(0.061)	(0.06)	(0.062)	(0.086)	0.085)
Population growth $_{t-1}$	-0.061***	-0.061***	-0.067***	-0.072***	-0.071***
	(0.012)	(0.012)	(0.012)	(0.016)	0.016)
Energy consumption $_{t-1}$	-0.457***	-0.47***	-0.401	-0.456***	-0.466***
	(0.089)	(0.09)	(0.089)	(0.124)	0.124)
Energy imports $_{t-1}$	-0.0004	-0.0004	0.0005	-0.0004	-0.0003
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	0.0004)
Renewable capacity $_{t-1}$	-0.092***	-0.095***	-0.091***	-0.06***	-0.057**
	(0.009)	(0.009)	(0.009)	(0.018)	0.018)
Constant	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations (N)	390	390	390	276	276
R-squared	0.661	0.664	0.652	0.524	0.525

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The stringency of wind and solar FiT schemes only exhibits a weak correlation with the total factor productivity of the economy. However, the level of installed renewable capacity, which was in many countries at least in part supported by these schemes, shows a strong negative relationship with the economy's total factor productivity: any 1% increase in renewable installed capacity was associated with 0.01% decrease in TFP.

There is little evidence that climate policies captured by the variables used in this analysis had any strong impact on the TFP of the energy sector. Pricing policies seem to have had only a small negative effect on the TFP of the energy sector. For every \$1 increase in the price of CO_2 emissions, the average decrease in TFP is 0.4%. The magnitude of this effect is slightly stronger for carbon taxes than emissions trading systems. This suggests that prices created by carbon taxes are driving the overall impact of carbon pricing on TFP. The distribution of these estimates is such, however, that they can only be confidently identified as different from 0 in the case of carbon taxes and all pricing mechanisms. A similar pattern emerges for the effect of FiTs (wind and solar separately) on the energy sector's TFP. Coefficient estimates for both variables are positive but there is little that these are statistically different from 0.

The observations made about the impact of carbon pricing policies on the energy sector's productivity contrast with those presented in most studies focusing on manufacturing sectors. Lutz (2016) and Calligaris et al. (2018) find a positive effect of carbon pricing on manufacturing firms in Germany and Italy, respectively. Both studies, however, investigated the impact of the EU ETS. Commins et al. (2011) and Martin et al. (2014) analyse the impact of carbon taxes, focusing on manufacturing sectors and came to opposing conclusions. The former study reports a negative impact of the tax while the latter reports an insignificant impact. We are not aware of any other analysis investigating the implications of carbon taxes for productivity in the energy sector.

Overall, with the exception of carbon taxes, these results do not support the hypothesis that climate policies have had a substantial *direct* impact on the productivity of the energy sector, either positive or negative. However, we note that an intended effect of these policies was to induce the deployment (and economic dispatch) of renewable energy generation capacity and that, across all estimated models, there is strong evidence that this deployment had a negative impact the energy sector's TFP. This suggests that more stringent climate policies weigh negatively on the productivity of the energy sector *indirectly*.

Table 9 – Effect of climate policies on energy sector productivity

	lnTFP (1)	lnTFP (2)	lnTFP (3)	lnTFP (4)	lnTFP (5)
ETS+Tax $_{t-1}$	-0.004*				
	(0.0019)				
Tax rate $_{t-1}$		-0.008**			
		(0.003)			
ETS price $_{t-1}$			-0.0014		
			(0.0024)		
FiT wind $_{t-1}$				0.0089	
				(0.0071)	
FiT Solar $_{t-1}$					0.0005
					(0.0066)
GDP per capita$_{t-1}$	0.6991***	0.7022***	0.6725***	0.8153***	0.8682***
	(0.1382)	(0.1376)	(0.1387)	(0.1948)	(0.193)
Population growth $_{t-1}$	-0.0841**	-0.0838**	-0.1377	-0.0846**	-0.1342***
	(0.0277)	(0.0279)	(0.0363)	(0.0276)	(0.0363)
Energy consumption $_{t-1}$	-0.6879***	-0.6905***	-0.5017	-0.7307***	-0.5163
	(0.2024)	(0.2019)	(0.2043)	(0.2795)	(0.2803)
Energy imports $_{t-1}$	-0.0026***	-0.0027***	-0.003*	-0.0027**	-0.0028**
	(0.0007)	(0.0007)	(0.0007)	(0.001)	(0.0001)
Renewable capacity $_{t-1}$	-0.1096***	-0.114***	-0.1234**	-0.1127**	-0.1178**
	(0.0197)	(0.0195)	(0.0199)	(0.0396)	(0.0397)
Constant	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations (N)	390	390	390	276	276
R-squared	0.613	0.616	0.607	0.431	0.428

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results presented above highlight differences in the implications of climate policies at the economy and energy sector level. While columns 1 to 5 in Table 9 provide no robust evidence of a *direct* impact of climate policies on energy sector productivity, economy-level models (Table 8, columns 1 to 5) suggest a negative average impact of carbon taxes on the economy's TFP. Taken together, these two observations point to the possibility that the negative impact of carbon taxes on the economy's productivity originated in other sectors than the energy sector. In particular, it might have originated in manufacturing sectors covered by carbon taxes. However, to date, virtually all studies have investigated the impact of the EU ETS and the few studies that have analysed the implications of carbon taxes for productivity, Commins et al. (2011) and Martin et al. (2014), focused on manufacturing sectors and came to different conclusions. This calls for further investigation of the role played by carbon taxes in determining manufacturing sectors' productivity.

The analysis highlights another important point: that climate policies can affect firm-, sector-, economy-level productivity through several channels. First, it can induce change in real capital and/or labour expenditures. As mentioned before, both carbon pricing and feed-in-tariffs have induced power generation utilities to invest in new renewable generation capacity.[28] However, given the intermittent nature of power produced by these generation technologies, their deployment has led to little retirement of older capital stock. A larger capital stock and relatively stable output in the energy sector might therefore explain part of the productivity slow down. The negative relationship between installed renewable capacity and productivity identified across all models estimated lends support to this explanation and points to an indirect link between support for renewable generation capacity deployment and TFP, i.e., one that is mediated through the

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[28] Alongside these two policies, Renewable Energy targets forced utilities to invest heavily in the deployment of renewable electricity generation capacity.

actual deployment of such capacity.

Second, climate policies could induce technological improvement leading to, for example, enhanced operational efficiency of existing or new plants. The strong version of the Porter Hypothesis posits that this would eventually lead to productivity improvements. However, results for the energy sector provide little support for this hypothesis in our context and results for economy-level models point to a negative effect of carbon taxes on productivity. This might be explained by the fact that higher renewable generation capacity reduces utilisation of existing fossil-fuel plants and hence reduce their productivity.

Third, we note that the productivity measure used in this study is based on value added, which is sensitive to variations in output prices. Since carbon pricing policies aim at raising the cost of polluting inputs to (or polluting by-products of) the production process, there is at least the theoretical possibility that some of the variation in output price resulting from such policies will be accounted for as a change in productivity (Lutz, 2016). The extent of this effect at the firm or industry level depends on the pass-through rate and pollution intensity. In the energy sector, there is some evidence that emissions costs are passed through to electricity prices by utilities (e.g., Fabra and Reguant, 2014), which would imply that some of the energy sector value added was not lost.[29] The question remains as to whether higher RES, by depressing gas and electricity prices, contributed to lower measured value added and hence productivity.

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[29] A more recent development with the potential to raise marginal cost is the increasing scarcity of suitable sites for utility-scale renewable power generation installation (Lancker and Quaas, 2019).

6. Discussion

Regulation of network industries has wide-ranging economic, social and political implications and, more often than not, is associated with trade-offs between economic and societal objectives. In our context, regulations aiming at reducing emissions in the energy sector may have had an adverse effect on the productivity of the sector, suggesting a trade-off between the sector's TFP growth and the attainment of environmental objectives. Our findings support such an interpretation as the results suggest that the addition of renewable capacity —accompanied by substantial increases in capital cost, in the face of lower wholesale prices, might lead to lower revenue and an attendant decline in productivity.

These results echo some of the earlier findings on the relationship between product market regulations and TFP growth, which suggests that high level product market regulations weigh negatively on TFP growth, especially in the European regulated market services (Van Ark et al., 2008 and Miller and Atkinson, 2014). Conway et al. (2006), for instance, argue that the incentive to invest in ICT is stronger in countries and sectors characterized by lower regulation. Relatedly, Nicoletti and Scarpetta (2003) provide evidence of a negative impact of the stringency of product market regulation on productivity growth in manufacturing industries.[30]

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[30] Some evidence of this is provided by Crafts (2006), who shows that restrictive product market regulations, especially entry barriers, hinder technology transfer and have a negative impact on productivity; and links the past TFP improvement in the UK to the apparent low level of regulation relative to France and Germany. Barone and Cingano (2011) also suggest that lower regulation increases the growth rate of value-added and productivity of manufacturing industries in OECD countries and find that there is a 0.7–1 percentage point growth differential between low regulation countries like Canada and more highly regulated countries like France. See also Bourles et al. (2013).

Furthermore, some analyses have pointed out potential unintended consequences of regulatory reforms. For example, Brau et al. (2010) posit that heavily regulated markets may have negative welfare effects since public ownership, vertical integration and market entry regulation distort the allocation of resources among sectors and firms, thereby weakening the overall economic performance. Regulation also affects the costs that incumbent firms face when increasing their productive capacity as regulatory pressures can push up costs in relation to capital stock adjustment (Alesina, et al., 2005).

Finally, we note that an important consideration for the validity of our results is whether product market and climate regulations are independent regulatory developments. In this regard, we make two observations. First, product market regulation reforms in the energy and gas sector predate the development of environmental policies targeting these sectors. Second, over the period of analysis —and to this day, product market regulations and climate policies have been developed as part of two independent processes pursuing independent objectives.

7. Conclusion

We have undertaken two sets of analysis in this paper examining TFP in a sample of OECD countries covering the period 1998-2016.

The first provided estimates of TFP growth in the whole economy and in the electricity and gas sectors, respectively. We contrasted sector-level and economy-wide TFP growth and investigated the correlations between the various productivity measures and their components over time. We find that there is a substantial productivity puzzle for the electricity and gas sectors specifically. TFP growth is lower in electricity and gas than in the economy as a whole and falls post-financial crisis.

The second focused on relating the level of TFP in both the whole economy and the energy sector to climate policies, as measured by carbon pricing and feed-in tariffs. We find evidence that energy and climate policy has negatively and significantly reduced energy sector productivity, at the same time as increasing capital input to the sector. Further, we find that the strength of energy and climate policy is positively correlated with lower economy wide TFP. We also note that these results are obtained at the sectoral and economy level and that the dynamics uncovered at the industry-level may be affected by resource reallocation among firms (Albrizio et al., 2017). Therefore, investigating the relationship between climate policies and productivity at the firm level should provide additional insights.

The results of our analysis have important policy implications. First, the productivity puzzle does exist in the energy network sectors, particularly in electricity and gas. If anything, there is more of a productivity puzzle in the electricity and gas sectors than in the whole economy. We clearly show that despite large amounts of capital being put into these sectors, TFP has fallen. This is worthy of further study.

Second, the productivity puzzle at the whole economy level in OECD countries would seem to at least be partly due to more ambitious environmental policy. Hence environmental policies need to pay more attention to their impact on productivity both within the electricity and gas sectors and across the whole economy.

Third, we do not find evidence for ‘green growth’ arising from more stringent and more input intensive environmental and renewables policies. Such policies bring welfare benefits in terms of a cleaner environment, but they do not appear in current measures of TFP. Advocates for ‘green growth’ strategies need to better measure and articulate the welfare benefits of such strategies.

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Appendix

Figure A1: Trends of Total Factor Productivity growth by Country

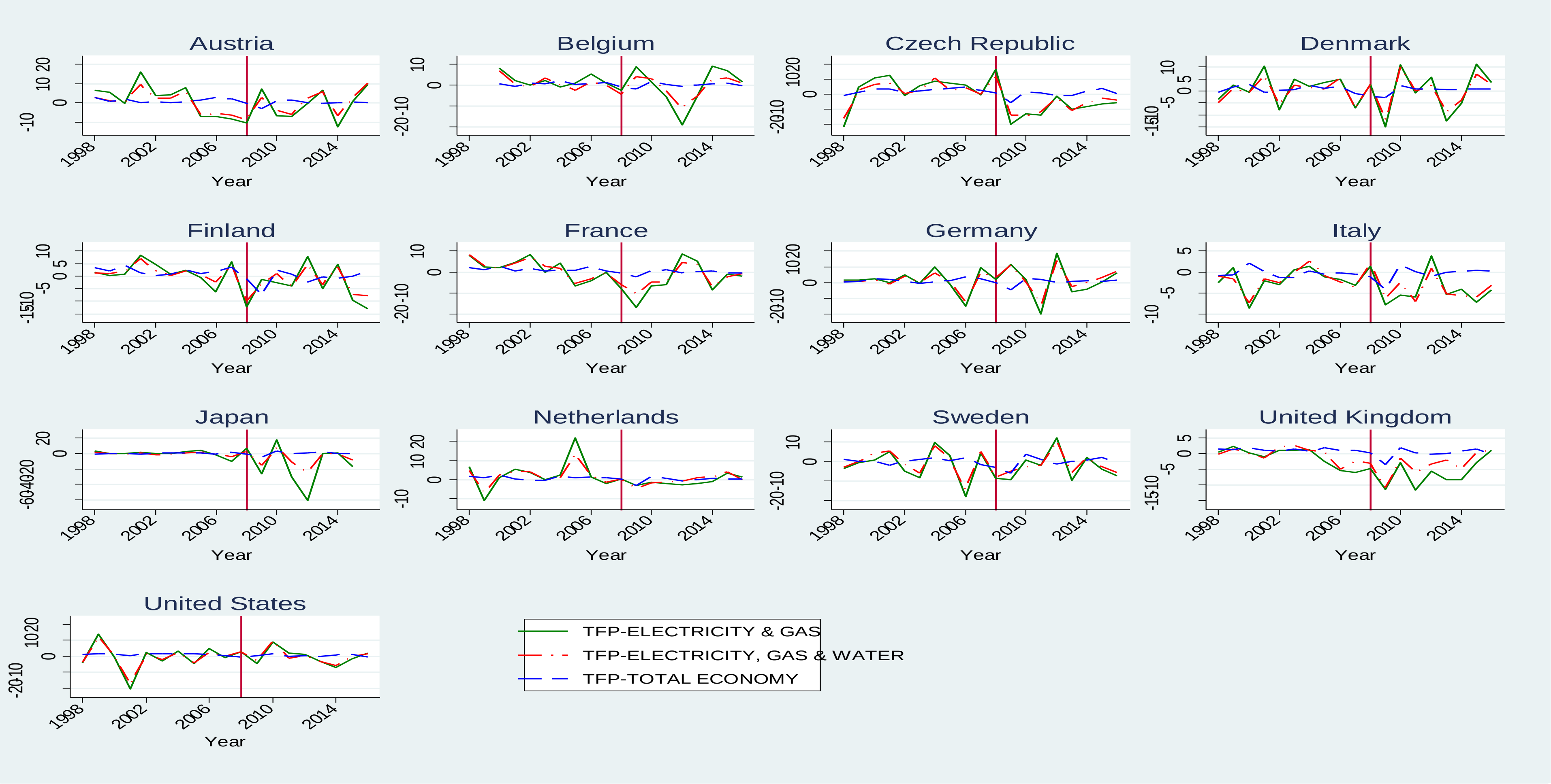

Table A1: Capital Input Growth Correlation-Total Economy

	IntangOIPP	*IntangRD*	*IntangSoftDB*	*TangICT*	*TangNICT*	*Capital input growth*
IntangOIPP	1					
IntangRD	0.1271**	1				
IntangSoftDB	0.0127	-0.2971***	1			
TangICT	0.1288**	0.1480**	0.1809***	1		
TangNICT	0.0247	0.0764	0.1049	0.2821***	1	
Capital input growth	0.1111*	0.2308***	0.2793***	0.5293***	0.9322***	1

Table A2: Capital Input Growth Correlation- Electricity and Gas Sectors

	IntangOIPP	*IntangRD*	*IntangSoftDB*	*TangICT*	*TangNICT*	*Capital input growth*
IntangOIPP	1					
IntangRD	-	1				
IntangSoftDB	-	-0.1023	1			
TangICT	-	0.0441	-0.0748	1		
TangNICT	-	-0.1009	-0.0044	0.1528**	1	
Capital input growth	-	0.0619	0.0240	0.3426***	0.9673***	1