Office for National Statistics

Compendium

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Chapters in this compendium

Compendium

An update on the transformation of the UK National Accounts

The next stages of our transformational work programme for the UK National Accounts, building on the new framework for producing current price and volume estimates of gross domestic product in the UK, introduced in Blue Book 2019.

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1 . Main points

- Blue Book 2019 marks a significant step in our transformation of the UK National Accounts, where we have implemented a new framework to inform the estimates for headline gross domestic product (GDP) and in which there has been more emphasis on data confrontation in the balancing of current price and volume estimates.

- Our work so far has highlighted a number of challenges in meeting the data demands of the new framework – and this will form the basis of prioritising our development work and is integral to our ability to produce high-quality estimates of double-deflated estimates of gross value added (GVA).

- We have initiated research, which includes improving the congruence of our microdata used in compiling GDP to help ensure we reflect our best quality information, a continuation of our deflator development programme with more alignment to the needs of double deflation, and a review of the level of detail we use to compile GDP.

- We plan to publish experimental estimates of double-deflated GVA alongside Blue Book 2020 and to implement double deflation into the UK National Accounts in Blue Book 2021 – the scope of this implementation will be conditional on the findings of our research programme and wider consultations.

2 . Introduction

The need for high-quality estimates on the UK economy has long been recognised by policymakers, economists and the wider public. This is in part reflected by the number of high-profile reviews that have been carried out on economic statistics in recent decades, whose scope have primarily reflected the pressing challenges of their time.

The most recent ones, led by Dame Kate Barker and Art Ridgeway (National Statistics Quality Review: National Accounts and Balance of Payments, 2014) and Sir Charles Bean (Independent Review of UK Economic Statistics (PDF, 5.13MB), 2016), relate to the statistical challenges that national statistical institutes face today. Many of these reflect the challenges of digitalisation and globalisation – features of the so-called modern economy – and specifically the increasing difficulty of measuring output and productivity in a "modern, dynamic and increasingly diverse and digital economy".

In identifying the needs and priorities of our users, several recommendations have been put forward to improve the compilation of the UK National Accounts. These range from tackling the long-standing statistical limitations to reflecting the changing structure and characteristics of the economy to exploiting more effectively existing and new data sources and technologies. This has helped transform the UK National Accounts. In recent years, this has led to a number of high-profile changes to the production of headline estimates of gross domestic product (GDP), which include the following.

A new GDP publication model

In looking to improve the trade-off between timeliness and accuracy of early estimates of GDP, specifically with a view of producing a higher-quality initial estimate that would be less susceptible to revision, we introduced a new GDP publication model in the UK in July 2018[1]. This was based on looking to incorporate richer information from the three approaches to GDP – output, expenditure and income – so providing the scope for a more informed picture of the UK economy. This also enabled the UK to become one of a select few countries to produce estimates of monthly GDP.

Value Added Tax

In contrast to some other national statistical institutes, short-term estimates in the UK National Accounts have traditionally been compiled using business and household surveys. There had been relatively limited use of administrative estimates, which have the potential to provide richer and more comprehensive estimates of activity taking place in the UK. In December 2017, we introduced [Value Added Tax (VAT) turnover] returns from 630,000 businesses in producing estimates of GDP to supplement turnover estimates from the returns from 45,000 businesses in the Monthly Business Survey[2].

Surveys

There are a wide range of challenges in recording services output as services become more complex and more important to the economy.The new Annual Survey of Goods and Services has led to a significant improvement in providing detailed information on the goods and services produced by each service industry. Furthermore, the need for up-to-date information on products used in production is of high importance, given how production processes change over time in response to advances in information and communications technology, the emergence of new industries and products, import substitution, organisational changes and behavioural responses to movements in input prices. We have reintroduced the Purchases Survey, which provides an up-to-date and more detailed estimate of the goods and services purchased by businesses by product as part of their production process.

A new framework

The aim of this article is to provide an overview of the next stages of our transformational work programme, building on the new framework for producing current price and volume estimates of GDP in the UK that was introduced in Blue Book 2019.

One of the core features of this framework is that it improves the coherency and consistency of how we produce GDP. Given the challenging nature of producing reconciled estimates of GDP, we will look to implement this in stages over the coming years. This confrontation in how we now produce GDP in a supply and use tables (SUTs) framework has played an important role in identifying some of the remaining challenges and helping drive our future development plans.

As we make progress on this next stage of transforming the UK National Accounts, we will take the next steps in producing double-deflated estimates of gross value added (GVA) in line with international best practice – the first time that these will be produced in the UK.

Notes for: Introduction

1. Previously, we produced three estimates of UK GDP each quarter, published 25, 55 and 85 days respectively after the reference quarter. That preliminary estimate was based only on the output measure of GDP. We have now moved to producing two estimates each quarter, in which the new first quarterly estimate of GDP is now published 40 days after the end of the reference quarter. It incorporates information from the output, expenditure and the income measure of GDP.

2. The purpose of incorporating VAT turnover estimates is to [improve coverage of smaller businesses for selected industries]. They are incorporated in the UK National Accounts with approximately a six month lag, so are not reflected in early estimates of monthly and quarterly GDP. We are continuing to assess and quality assure the VAT estimates, with a view to expand their scope in the construction, production and services industries.

3 . A new framework for gross domestic product (GDP)

In the UK National Accounts, balanced estimates of current price gross domestic product (GDP) have historically been produced in a supply and use (SUTs) framework. Volume estimates of GDP were then produced using the expenditure approach to deflate nominal GDP. Previous analysis highlighted that, while the expenditure approach to GDP reflected the best information that has been available in the UK, better quality estimates could be used by also using information from the production measure for some parts of the economy. In addition, there were a number of conceptual challenges in how this was previously undertaken.

Reconciliation of volume estimate

Whilst current price estimates are fully reconciled in a SUT framework using a 112 product by 112 industry matrix, volume estimates are effectively reconciled at the aggregate GDP level only. Although the detailed estimates are used to inform the approach, balancing adjustments are applied inconsistently and can lead to implausible implied deflators.

Separate current price and volume balancing

The process is very sequential and does not allow to revisit the approach to balancing in current prices once deflation has taken place and volume estimates are available. As such, information that could be used to inform the current price balance is not available, which may have led to different balancing decisions.

Blue Book 2019

The wider implementation of this new framework has helped enable progress on these points. We anticipated the scale of these improvements to be significant. Given the extent of these challenges and the importance to understand fully the impacts of double deflation on industry gross value added (GVA), we decided to use our pre-existing approach to produce industry-level estimates this year and that it will be more appropriate to implement double deflation in stages over the coming years. That said, Blue Book 2019 marks the first step on this journey, and some of this progress has helped inform headline GDP estimates this year. In particular:

- progress in incorporating a wider set of more appropriate available product deflators for each transaction, confronting these at a detailed level for the first time
- integrated the institutional sectors into the balancing process of the SUTs framework, enabling us to check simultaneously the coherence of current price GDP, volume GDP and the sector and financial accounts in their compilation
- improved our estimates of current price GDP by using new data sources to give information on the diversification of the services economy and the costs incurred by businesses

4 . Double deflation

The implementation of this new framework will also enable the production of double-deflated gross value added (GVA) at the industry level for the first time in the UK. Double deflation has long been considered the best way to produce volume estimates of GVA, and so has been a core theme of the National Statistics Quality Review: National Accounts and Balance of Payments (2014) and the Independent Review of UK Economic Statistics (PDF, 5.13MB) (2016). This is where the nominal value of output and intermediate consumption for an industry is deflated by the best available price index for that transaction. In the absence of output and input being deflated separately, it can be shown that this can lead to a bias in estimates of industry-level GVA.

Double deflation helps improve our understanding of productivity analysis. Under single deflation, the price movements are implicitly the same for output that is sold and intermediate inputs that are bought. If this does not hold, then single-deflated estimates of industry-level GVA will be subject to bias – and this will be more pronounced:

- the larger the difference between output and input prices
- the higher the share of intermediate consumption of GVA[1]

Whilst this new framework has the potential to help produce more coherent and consistent estimates of gross domestic product (GDP), one of the major challenges is that it is highly dependent on high-quality information feeding into the compilation process. As identified in some of these reviews, there are instances where this is not always the case – and that can lead to producing estimates that may not always appear economically coherent. As such, the experience of this year's Blue Book has helped us identify priority areas where further improvements are needed – and this will form the basis of developing the UK National Accounts over the coming years. These include the following.

Data source review

Building on these findings of this year's Blue Book, we will look to carry out a systematic assessment of our current data sources, identifying where new ones may be required to improve how economic activity is recorded. This will help us improve how we produced balanced estimates of current price and volume GDP. We will also undertake more research in being able to improve how we reflect insights from our microeconomic analysis in producing our macroeconomic estimates.

Deflators

In undertaking a review of how our deflators scored against a range of quality considerations in this year's Blue Book, we identified a number of high-priority improvements that are integral to understanding the impact of double deflation. We will look to implement some of these improvements over the coming years, which will include understanding the extent to which we capture domestic and foreign price movements in our goods and services deflators and the appropriateness of how we adjust for changes in quality over time. It has long been recognised that this has been a pressing concern in the services industries, particularly those that are prominent in the modern economy.

Another feature is the need to improve our reconciliation of supply-side and demand-side deflators, as this will help us produce more consistent estimates in balancing supply and use of current price and volume estimates of GDP at a product level. Our work this year also highlighted that there is a need to review some of our historical estimates, particularly those pre-2008.

Products

The supply and use table (SUT) framework is the most comprehensive one available, in which we look to balance demand and supply for each good and service at the lowest level possible. This necessitates having precise information at this level, and so we will review the quality of the products in the SUT framework.

This will specifically be in relation to the underlying current price estimates and deflators at the product level, and how this relates to the balancing process of current price volume estimates. There may also be scope to exploring the feasibility of expanding the product breakdown in the SUT framework, particularly as economic activity becomes more heterogeneous in nature in the modern economy.

Reconciliation of SUT and quarterly balancing

In tackling some of the limitations that are inherent in the absence of double deflation, this will help identify where we may be able to improve the process of SUT balancing and so lead to producing estimates of GDP in a more coherent and consistent manner. This will include research into the link between annual estimates of industry-level estimates of double-deflated estimates of GVA and quarterly estimates that are produced by single extrapolation in those periods that have not been balanced in a SUT framework.

It will also reflect how we are now able to produce more consistent estimates of current price and volume GDP in a SUT framework, and how this is better reflected in producing quarterly estimates in those years that have not been fully balanced.

Blue Book 2020 and 2021

Given that we expect applying the SUT framework to be a challenging process , we plan to publish experimental estimates of double-deflated GVA in Blue Book 2020 and to implement double deflation into the UK National Accounts in Blue Book 2021. The scope of this implementation will be conditional on the findings of our research programme and wider consultations while, as part of continual improvements, we will also continue to look at some of the wider principles of this new framework in producing current price and volume estimates of GDP in subsequent Blue Books.

Notes for: Double deflation

1. Furthermore, for those periods that have not yet been subject to full balancing in a SUT framework we estimate headline and industry-level volume GVA using single extrapolation. That is, the change in output is considered a proxy of the change in GVA. That may hold in stable times of the cycle, though it could be argued that it is less likely to be the case around turning points or if there are sharp movements in the relative price of output and input.

5 . Conclusions

In the Independent Review of Economic Statistics, several challenges are identified in how we measure the UK economy. It was recommended that work be undertaken to further develop our statistics, which included:

- developing estimates of double-deflated volume measures of GDP
- exploring the scope for improving early estimates of GDP through the use of administrative data, including by making greater use of information from the expenditure and income measures
- putting in place more detailed and complete flow of funds statistics
- better measurement of the services sector, including the need for more detailed deflators and volume indices
- further developing regional statistics harnessing the potential for administrative data

In recent years, we have undertaken a work programme to help respond to these challenges. We have introduced a new gross domestic product (GDP) publication model to improve the trade-off between the timeliness and accuracy of early estimates, which has allowed the UK to be one of the first countries to develop monthly estimates of GDP. We have incorporated estimates of Value Added Tax (VAT) turnover to improve how we produce the output measure, which also helps enable the production of timely and more frequent estimates of regional GDP. Furthermore, we continue to make considerable progress in the development from-whom-to-whom flow of funds.

Blue Book 2019 marks a significant step in our transformation of the UK National Accounts, where we have used the foundations of a new framework to inform the estimates for headline GDP. There has been more emphasis on data confrontation in the balancing of current price and volume estimates, while we have incorporated new survey information to improve our understanding of the structure of how GDP is produced. However, this new framework has also highlighted the next steps we need to take in producing the UK National Accounts, and this forms the basis of the next stages of our development of the compilation process. This is integral to our ability to produce high-quality estimates of double-deflated estimates of gross value added (GVA) for the first time in the UK. Given the extent of the challenges, we have decided that it will be more appropriate to implement double deflation in stages over the coming years and not this year as initially planned. That said, this new framework has also highlighted the next steps we need to take in producing the UK National Accounts, and this forms the basis of the next stages of our development of the compilation process. This is integral to our ability to produce high-quality estimates of double-deflated estimates of GVA for the first time in the UK.

We plan to publish experimental estimates of double-deflated GVA in Blue Book 2020, reflecting initial progress on the research areas identified here. As these are developed further, we aim to incorporate double-deflated estimates of real GVA into the UK National Accounts in Blue Book 2021.

The scope of this implementation will be conditional on the findings of our research programme and wider consultations, which will provide further insights into some of the feasibility considerations, particularly to historical estimates. Once fully implemented, its impact is expected to lead to improved quality estimates of volume GDP and productivity analysis.

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Compendium

Regional estimates of gross domestic product

An analysis of economic statistics development and trends. The compendium Economic Review is published quarterly, usually in January, April, July and October.

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1 . Introduction

There has been an increase in user demand for better understanding the performance of the countries and regions in the UK. This need for timelier and more frequent subnational estimates of economic activity reflects not only a shift towards the devolution of powers, but also for helping policymakers and researchers understand how performance at the regional level can help explain recent economic and social trends. Recent analysis (PDF, 2.09 MB) highlights how this has been reflected in understanding how economies operate at a local level, calling “for new data, at a higher frequency and higher resolution and new ways of stitching it together”.

The Allsopp Review (2004) provided recommendations to improve subnational economic statistics, including a focus on better quality and more timely measure of real regional gross value added (GVA) and expanding the range of micro-economic and sub-regional information that was available. The Independent Review of UK Economic Statistics (PDF, 5.13MB) identified some of the key challenges in the measurement of the UK economy, including “inadequate regional statistics”. One of its key themes was to improve the coverage and timeliness of subnational estimates, exploring the potential for administrative data to fill some of these gaps. Historically, we have produced subnational estimates of gross domestic product (GDP) on an annual basis, produced with a lag of around a year. Research undertaken by the Economic Statistics Centre of Excellence (PDF, 876KB) has focused on improving the timeliness and frequency of these estimates in the UK, so that a much more comprehensive regional picture of the UK economy can be produced that helps users understand the local experience of households and businesses[1].

This article explains how we have produced quarterly estimates of GDP for the nine English NUTS1[2] regions and Wales. These experimental estimates, coupled with the existing estimates for Scotland and Northern Ireland, provide a complete subnational picture for the UK economy for the first time. It then offers new insights into how the UK regions have performed lately, highlighting how and why these regional estimates are inherently more volatile than UK GDP, but can help provide more insight in explaining headline movements in the UK economy. It reconciles these new indicators with the latest regional productivity estimates in helping explain the economic performance of the regions in the UK. We then outline some of the proposed development to these experimental estimates, as we look to improve how we estimate subnational activity with a view to these becoming National Statistics.

Figure 1: GDP growth for NUTS1 regions in the UK, Quarter 4 (Oct to Dec) 2018

Notes for: Introduction

1. “Nowcasts” of gross value added (GVA) for the UK regions have been produced, which are available around 45 days after the reference quarter. These are based on a mixed frequency Vector Autoregressive model in which restrictions are imposed such that these estimates are consistent with the official annual regional figures and the quarterly UK totals. Furthermore, historical estimates of nominal and real GVA growth have also been developed back to 1970 for each NUTS1 region of the UK.

2. NUTS, within the UK, refers to Nomenclature of Territorial Units for Statistics (NUTS) areas.

2 . Producing experimental estimates of regional gross domestic product

In September 2019, we introduced country and regional volume estimates of gross domestic product (GDP), with additional granular industry-level information for the nine English regions and Wales for the first time. This complements the estimates for Scotland and Northern Ireland produced elsewhere, thereby providing a complete subnational picture for the UK[1]. The production approach to GDP is often referred to as the output approach, as not all the information is available to fully measure all production activity in the economy. As such, production is approximated by recording output, which in turn is estimated by turnover. Gross value added (GVA) is considered a proxy of our short-term estimates of GDP and, as we consider the relationship between output and intermediate consumption to be similar over short time horizons, this allows VAT turnover to help us produce estimates of regional GDP.

Further information on introducing GDP for the countries of the UK and the regions of England is available for a more in-depth explanation of how this administrative information has also allowed us to develop regional estimates of GDP. In short, we apportion the VAT turnover for each business based on their employment share within any region[2]. While this tends to be a reliable proxy for regional activity, it also highlights the possibility of different activities taking place at different sites – and as such there might be variation in industrial classification between regions and UK measurement. In such instances where this may not be the most reliable indicator of where that activity is taking place[3] , we will look to exploit information from other direct regional indicators. These new industry estimates of regional GDP are based on the activity of the site, in line with how we produce our annual estimates of the regional accounts[4].

Notes for: Producing experimental estimates of regional gross domestic product

1. These regional estimates of GDP are produced by the Scottish Government and the Northern Ireland Statistics and Research Agency respectively. The Scottish estimates provide comparable industry-level estimates of output, while the Northern Irish estimates provides estimates for construction, production and services, as well as a private-public split.

2. The construction estimates here are sourced from the current price, non-seasonally adjusted subnational estimates published alongside the monthly Construction output publication. These data are modelled from new orders data via project-level information collected from Barbour ABI. These data map the projects' geographic locations, the specific duration of projects, and factor in the project start date and lag time from the order being placed to the project commencing.

3. In producing estimates of output for public sector industries, a mix of VAT turnover for market output and government expenditure for non-market output is used.

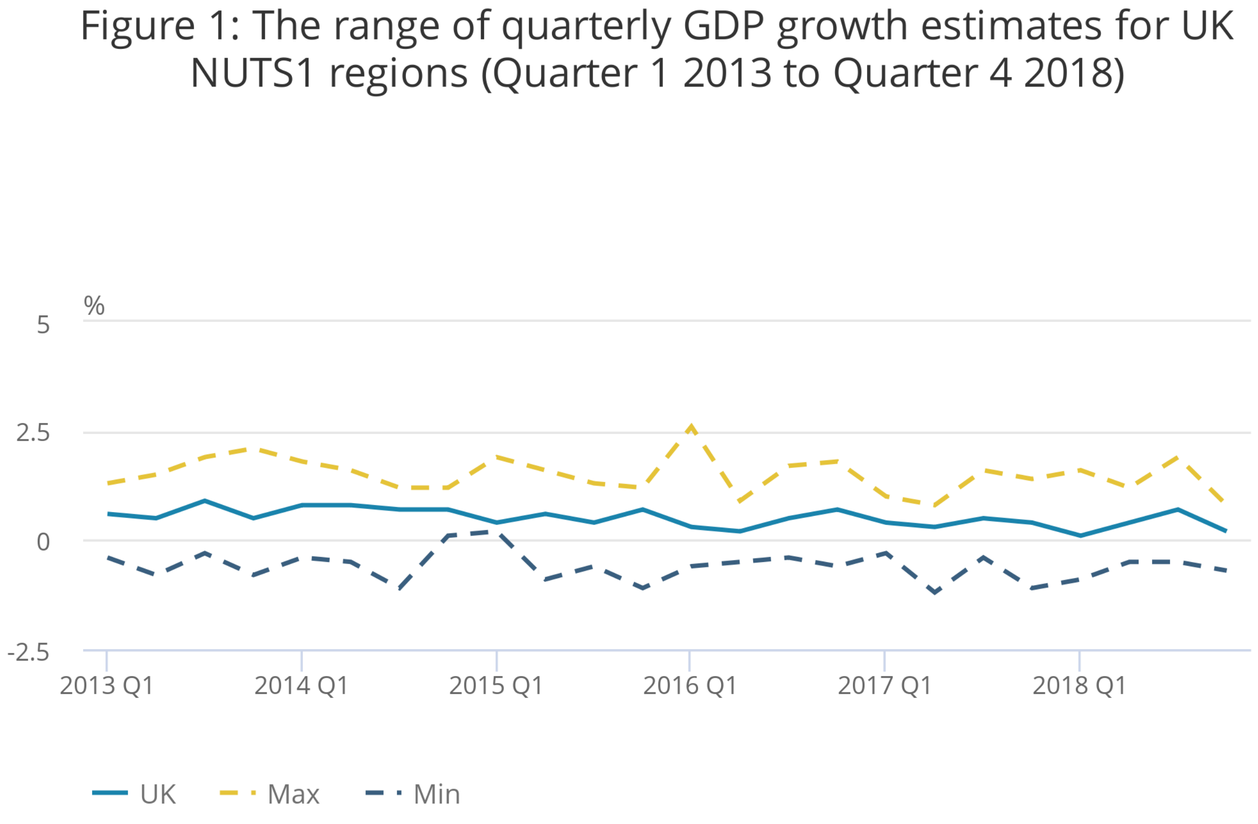
4. Estimates of economic activity published by Scotland and Northern Ireland are based on an industry classification that is a hybrid between the site-level activity and the overall business activity. However, the overall business and the site are the same for most businesses. While the actual difference between the estimates based on the two different classifications is not known, it is believed to be small.

3 . The economic performance of the UK regions

Regional gross domestic product (GDP) estimates show the extent to which economic performance has varied across the UK. Figure 1 shows UK GDP growth from 2013 onwards, comparing it to the range of economic performances at the subnational level[1]. The UK economy has been relatively steady in recent years as GDP has increased by 0.5% each quarter on average. The latest official estimates show that the UK economy contracted by 0.2% in Quarter 2 (Apr to June) 2019, in part reflecting changes in the timing of activity related to the UK's original planned exit date from the European Union in late March. Regional GDP estimates are only available up to the end of 2018, so 2019 figures are not included in this comparison.

However, the picture is much more mixed at the subnational level, highlighting the extra volatility in the regional estimates. For instance, at least 1 of these 12 NUTS1 regions has experienced a fall in output for most of the quarters covered here, as it is much more frequent for a region to experience contracting output than it is for the headline UK economy. It is also the case that individual regions are more capable of experiencing faster growth than the UK economy. For example, the UK has not seen quarterly GDP growth in excess of 1% over this six-year period, but at least one region has experienced that for most of this period.

Figure 1: The range of quarterly GDP growth estimates for UK NUTS1 regions (Quarter 1 2013 to Quarter 4 2018)



Source: Office for National Statistics, the Scottish Government, and the Northern Ireland Statistics and Research Agency - Economic review

Notes:

1. Real GDP figures are chained volume estimates that are adjusted for the effects of inflation over time.

2. UK GDP estimates are taken from the June 2019 quarterly national accounts, which are consistent with the regional GDP estimates here. These UK estimates include extra-regio figures; this is UK economic activity that cannot be attributed to a region, such as offshore oil and gas extraction and activities of UK embassies and forces overseas.

3. In more recent periods, gross value added (GVA) and GDP are not fully aligned except in the very latest two quarters where balanced GDP and GVA will be equal. The regional estimates of GDP are aligned to the official estimates of output GVA.

4. The minimum and maximum figures here capture the range of quarterly GDP growth estimates of all the 12 NUTS1 regions, as it refers to the maximum and minimum figures across all regions at a particular point in time. That is, these will not necessarily relate to the same region over time.

The much higher volatility in the regional estimates may reflect the industry composition at the sub-national level, in which certain industries are more likely to experience large fluctuations and/or that specific industries are relatively more exposed to shocks. For example, if a power station experiences a temporary shutdown, it is likely to have a large impact on its region because it is a major part of the electricity industry in that place. However, the impact is likely to be much smaller on the UK economy, not only because of the existence of many other power stations elsewhere in the UK, but because those plants will likely pick up much of the slack from the temporary closure.

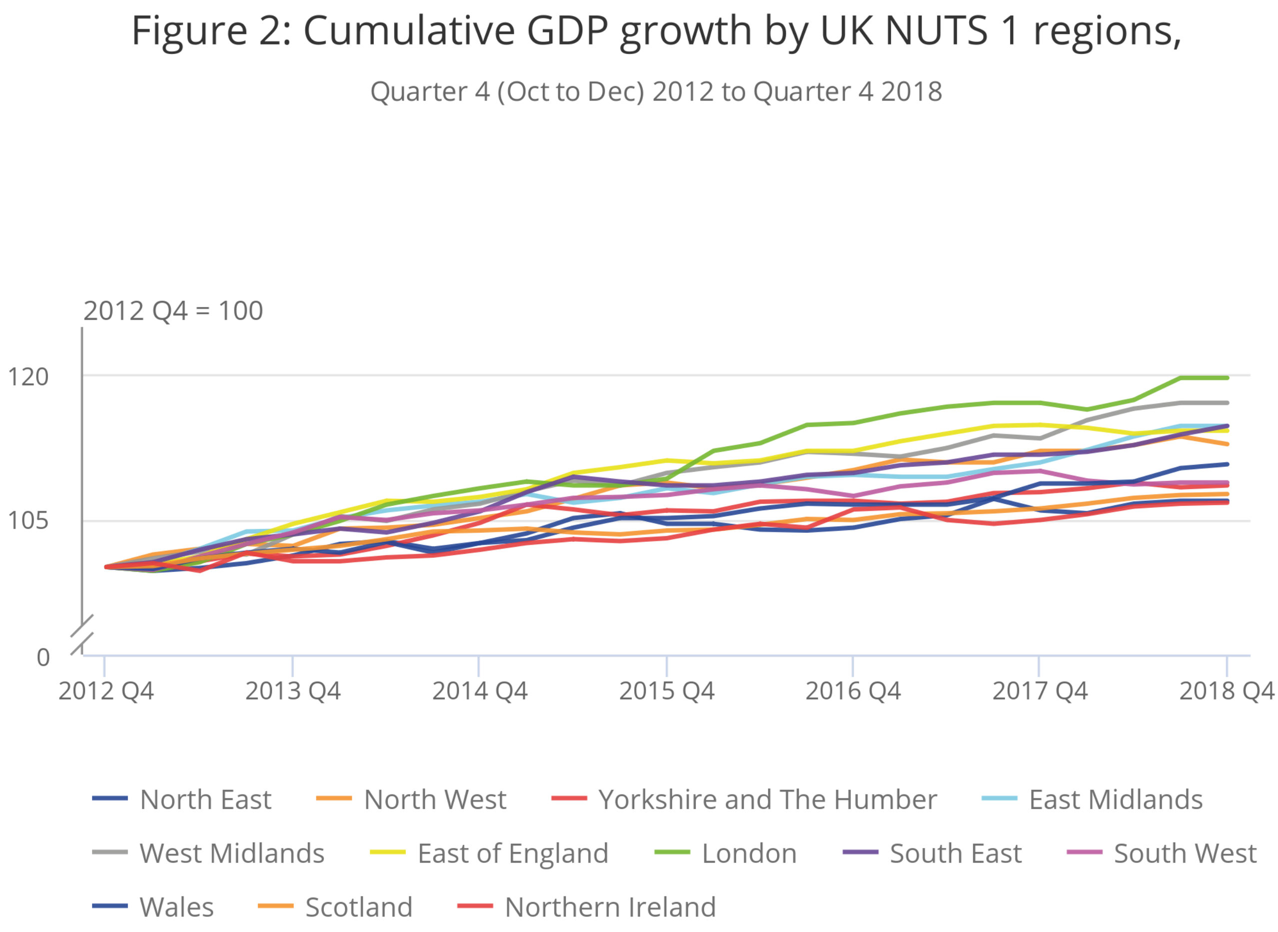
Regional GDP estimates also allow us to provide a richer understanding of notable movements at the whole economy level. For instance, the UK economy was hit by a number of “special events” in 2012, which led to a particularly volatile path through the year. Following a contraction in the second quarter, there was a large rebound in activity in the third quarter, before contracting once more in the final quarter of the year. One of the factors that played a role in this path is the London 2012 Olympic and Paralympics Games [2], bringing increased ticket sales to the UK in Quarter 3 (July to Sept) 2012 [3]. These effects are highlighted in the regional estimates here – although the UK economy increased by 1.2% in the third quarter, all but one of the English regions experienced a contraction in GDP. The one exception was London, which increased by 1.7% over that quarter, reflecting the increase in administrative and support service activities.

In studying the recession profiles within the UK, the Economic Statistics Centre of Excellence (PDF, 241KB) find that “regional cycles are more volatile and often de-couple from the path of the UK as a whole”, highlighting the variation around the frequency and timing of recessions. While these new estimates of regional GDP do not cover a recession episode for the UK economy, it is still possible to look at the extent to which there has been such regional variation in recent years.

Figure 2 shows the cumulative GDP growth of the 12 NUTS1 regions, providing a fuller picture of how wide ranging the regional performances have been. For instance, the London economy has increased by 19.7%, while Northern Ireland has only increased by 6.7% over the same period. Furthermore, these headline figures do not necessarily pick up how the shape of the profiles have shifted over time – for example, there are instances where regions have experienced technical recessions over this six-year period, although the regional estimates are much more inherently volatile. Instead, it is more striking though that it is not only that the underlying trends vary by region, but these regional trends have not been the same over time. This reflects that there are also dynamic effects here, which may be more useful in picking up cyclical and structural factors at the subnational level.

Figure 2: Cumulative GDP growth by UK NUTS 1 regions,

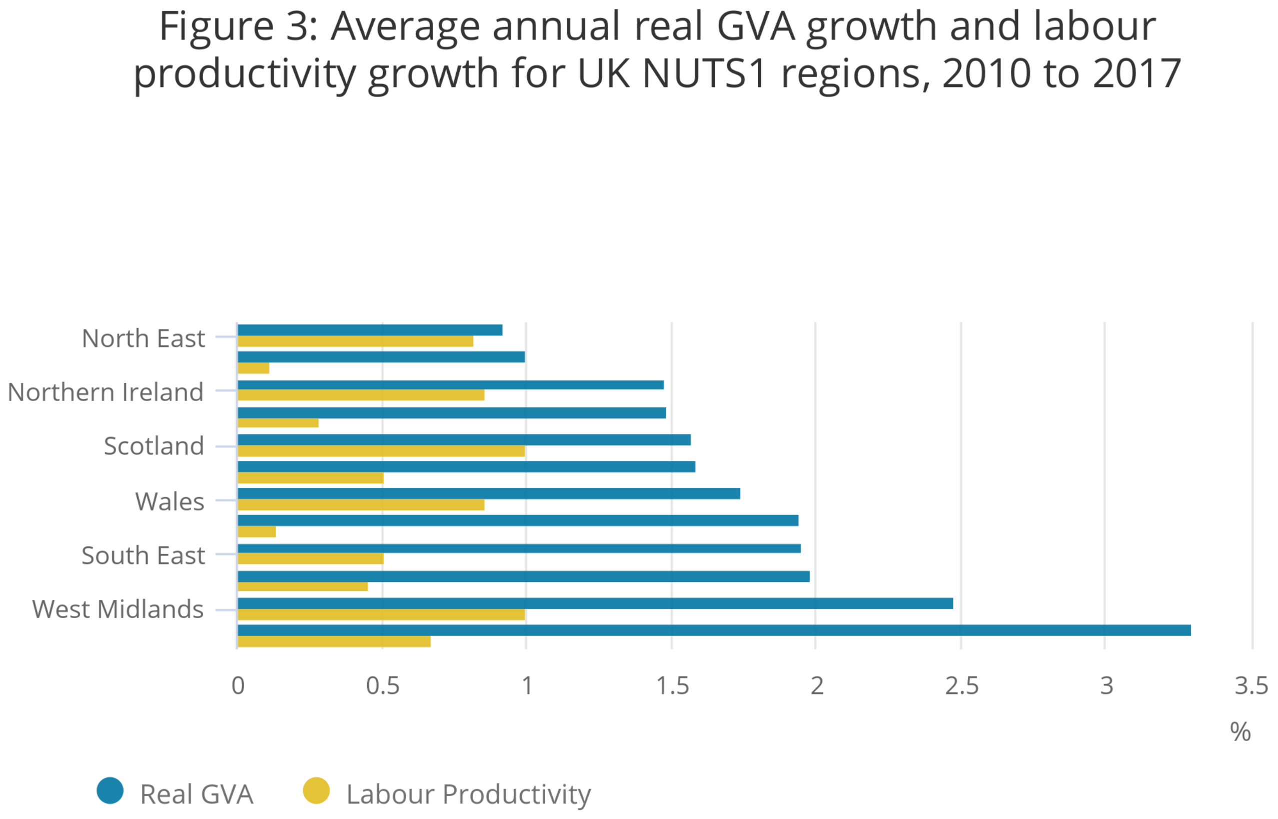
Quarter 4 (Oct to Dec) 2012 to Quarter 4 2018



Source: Office for National Statistics, the Scottish Government, and the Northern Ireland Statistics and Research Agency - Economic review

However, these figures do not provide much insight into regional inequality in the UK, as these do not take into consideration the productivity of each region. Regional differences in output growth will reflect changes in the rate at which factor inputs have been accumulated and/or regions being better at becoming more productive in how much output is produced per hour. Figure 3 shows the relationship between the average annual change in real gross value added (GVA) and labour productivity for each of the NUTS1 regions over the post-crisis period from 2010 to 2017, based on the latest regional productivity estimates. It shows that while London did see the largest annual increase in output over this period on average, this largely reflects it also experiencing the largest average increase in hours worked in the region. Annual productivity increased by an average of 0.7% per year over this period, which was only sixth fastest of the 12 NUTS1 regions. Similarly, while Northern Ireland did see the smallest average increase in output over this period, this was explained to some extent by it experiencing a relatively small increase in labour input. Productivity growth in Northern Ireland over this period was only behind the West Midlands and Scotland.

Figure 3: Average annual real GVA growth and labour productivity growth for UK NUTS1 regions, 2010 to 2017



Source: Office for National Statistics - Economic review

Previous analysis offers some further insights as to why there may be these differences in regional productivity. It found that it was not likely to reflect the composition of the industrial structure of that region, as "even within single industries we can observe large differences in average productivity levels between different parts of the country, particularly in services industries". Instead, it finds that there is some evidence that points to the importance of "internal factors" that impact upon firm-level productivity, such as whether that business is foreign-owned or if it exports, and "external factors" that relate to the location. External research on the productivity puzzle (PDF, 987KB) looks at explaining the distribution of firm-level productivity over time, including analysis of firm characteristics of those in the upper and lower tails of that distribution. While recognising that there are marked differences in average productivity across UK regions, it finds that "regional differences are not the main factor explaining the UK's long tail of firms nor why this tail is longer in the UK than elsewhere", as every region has frontier firms in the upper tail and laggard firms in the lower tail.

Notes for: The economic performance of the UK regions

1. Given that the effects of the Queen’s Diamond Jubilee and the Olympic and Paralympic Games led to a sizeable reprofiling of economic activity through 2012, these figures have been excluded from the analysis shown in this article.

2. As part of the balancing process in producing headline estimates of UK GDP, adjustments would have been applied in real time to take into consideration the London 2012 Olympic and Paralympics Games to reflect our best judgements of its effects. These would not have been reflected in the regional GDP estimates here.

3. Another factor was the bounce-back that took place in Quarter 3 (July to Sept) 2012, as the celebrations for the Queen’s Diamond Jubilee led to an additional bank holiday in the previous quarter.

4 . Conclusions

It has long been recognised that economists and policymakers that are interested in the subnational performance of the UK have typically faced a lack of timely and high-frequency regional estimates. This has impacted upon their ability to understand subnational dynamics and how this might help explain macroeconomic trends. One of the key themes of the Independent Review of UK Economic Statistics was to improve the coverage and timeliness of subnational estimates, specifically exploring the potential for administrative data to fill some of the gaps. As part of the transformation of the UK National Accounts, we have introduced country and regional volume estimates of gross domestic product (GDP), with additional granular industry-level information for nine English regions and Wales. These experimental estimates, coupled with the previously published estimates for Scotland and Northern Ireland, provide a complete subnational picture for the UK economy for the first time.

This analysis shows that while the UK economy has been relatively steady in recent years, the picture is much more mixed at the regional level. It is much more common for individual countries and regions to experience more volatile movements in its economic output, which in part may reflect that industrial composition of that region as certain industries are more likely to experience large fluctuations and/or that specific industries are relatively more exposed to shocks. The production of more timely and frequent estimates of country and regional GDP can help provide more insight in explaining the movements in the headline estimates, particularly if these are likely to reflect one-off movements that reflect region-specific effects. The latest headline estimates show that the UK economy contracted by 0.2% in Quarter 2 (Apr to June) 2019, following an increase of 0.6% in the first quarter of the year. However, this in part reflects changes in the timing of activity related to the UK’s original planned exit date from the European Union in late March[1]. The development of these new regional estimates of GDP will help offer further insight as to where these timing effects were most prevalent in the UK, providing users with more information as to where such shifts in activity was taking place[2]. The next set of subnational estimates will be published on 30 October 2019, including figures for Quarter 1 (Jan to Mar) 2019 for the first time.

As these estimates are experimental, we will continue to work on their development. These include the following.

Our regional GDP estimates aim to produce the best estimates at a subnational level. However, the sum of the UK regions may not equal the national total, reflecting that there are some differences in data sources and methods. We have constrained our regional GDP estimates in such a way that minimises the changes to the region by industry quarterly growth rates. While the overall impact of this constraining on the regional estimates is small, we are continuing to examine the impact of this range of options before deciding which one is best suited to these data in advance of applying to be assessed as National Statistics.

Following the announcement by the UK Statistics Authority in March 2019, Construction output price indices, Great Britain construction output statistics and Construction new orders were re-designated as National Statistics. It was noted, however, that the subnational and subsector breakdowns were excluded from consideration because of concerns around the path of the sub-national estimates of construction output. We have worked closely with the Construction Statistics Steering Group and Consultative Committee on Construction Industry Statistics (CCCIS) on improving these estimates. While While these users have acknowledged the improvements in the modelling of these estimates, there is ongoing development work to improve these lower-level estimates as we ultimately look to regain National Statistic status in due course. Any developments in this area will in turn lead to improved accuracy in the Regional GDP estimates.

Flexible geographies in the regional accounts build data up from lower-level “building blocks”, allowing the user to define the higher-level area required. We can already build up from local authority, but we hope to eventually build up from workplace zones. The development of flexible geographies in the regional accounts should allow us, in time, to blend these methodologies together to provide quarterly GDP estimates for any user-specified area. This work will be developed over the next five years.

We plan to publish a consultation later this year, which will pick up some of these topics and explore wider consideration so that we are able to respond to user needs in the most effective manner.

Notes for: Conclusions

1. Stockbuilding can take place in response to unexpected fluctuations in demand or when businesses simply choose to hold a different level of inventories of final or intermediate goods. This may have been particularly prevalent this year, given the heightened uncertainty around whether there would be disruption to cross-border supply chains. It was also reported that several car manufacturers had brought forward their annual shutdowns to April as part of contingency planning.

2. The latest nowcasts produced by the Economics Statistics Centre of Excellence show that Northern Ireland, the South East, the South West, Wales and Scotland experienced a contraction in output in Quarter 2 (Apr to June) 2019. That said, the confidence intervals around these quarterly estimates are larger than for the headline nowcasts, so these quarterly estimates are subject to higher levels of uncertainty. The latest experimental estimates by the Northern Ireland Statistics and Research Agency (NISRA) show that the volume of economic output increased by 0.3% in Quarter 2 2019.

5 . Authors

James Scruton, Bethan West and Sumit Dey-Chowdhury

Compendium

Comparing ONS’s economic data with IHS Markit and CIPS Purchasing Managers' Index surveys

A comparison between official estimates of UK output and diffusion indices, looking at the level of correlation between Office for National Statistics data and IHS Markit and Chartered Institute of Procurement and Supply Purchasing Managers’ Indices

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1 . Main points

- This article investigates the coherence of Office for National Statistics (ONS) Monthly Business Survey (MBS) data and the corresponding Purchasing Managers' Index® (PMI®) surveys from IHS Markit and the Chartered Institute of Procurement and Supply (CIPS).

- PMIs show the strongest relationship with ONS three-month on three-month a year ago data, with significant and sustained correlations found between the two datasets.

- Despite asking about month-to-month variations, PMIs have no significant correlation with ONS month-on-month MBS diffusion indices or official estimates of growth.

- This may suggest that PMI respondents take a wider and longer-term view of business conditions than just month-to-month variations as well as allowing for seasonal and other distorting factors.

- Even when official estimates and diffusion indices share the same base data, the difference in methodologies can produce two series with no significant correlation.

- Diffusion indices created from the MBS show similar tendencies to over or underestimate during economic shocks that are seen in the PMIs, though the rarity of economic shocks means that the sample size for this is small.

2 . Introduction

The official estimates of monthly output in the construction, manufacturing and services industry releases inform users of the state of the economy. Important users such as policymakers and forecasters are also interested in timelier indicators of economic performance, such as the Purchasing Managers' Index (PMI), which can be used to extract an earlier signal on the UK economy. The PMIs are reported monthly but released earlier than official estimates, providing one of the first indications of UK economic performance. Recent innovations also include faster indicators of economic activity based on Value Added Tax (VAT) returns.

Because of the different methodologies used in official estimates of output and in diffusion indices, these indicators can show different results for the performance of the various sectors in the UK economy. This article seeks to build upon work done previously to investigate the statistical coherence between official estimates and diffusion indicators such as PMIs.

Office for National Statistics (ONS) data are regularly reviewed as part of annual updates and reviews of both sources and outputs for consistency. This can lead to revisions to the published estimates. The different vintages of data may have different properties and earlier vintages may have slightly different levels of correspondence with the IHS Markit PMIs. The latest data we have available were used as part of this analysis.

3 . Case study: Differences between published ONS and IHS Markit and CIPS PMI data

Table 1 summarises the main difference between published Office for National Statistics (ONS) outputs and IHS Markit Purchasing Managers' Index (PMI) data, more information can be found on Markit's website.

Table 1: Summary of the differences between ONS official estimates of output and IHS Markit PMIs

	Published ONS outputs	IHS Markit PMI
What does it measure?	Businesses are asked to provide the monetary value of work in £ for the latest month.	Businesses are asked whether the volume of their output (in units) has increased, decreased or stayed the same compared with the previous month.
How is it presented?	Current price and volume estimates of output.	A diffusion index between the percentage of responses that show business performance as having increased, stayed the same, or decreased.
Timeliness of releases	Published approximately six weeks after the reference period.	Published between the first and third working day after the reference period.
Sample size differences	Services: Around 27,000 businesses. Construction: Around 8,000 businesses. Manufacturing: Around 6,000 businesses. Monthly Business Survey (MBS) survey panels are stratified by Standard Industrial Classification (SIC) group and company workforce size. The sample is dynamic, using random sampling for small and medium businesses while large business are always surveyed.	Services: 650 businesses. Construction: 150 businesses. Manufacturing: 600 businesses. PMI survey panels are stratified by SIC group and company workforce size.
Coverage	Broadly the same for the manufacturing and construction sectors, however approximately one half of the services sector gross value added (GVA) weights is not covered by the services PMI but is included in the Index of Services. Full details of the difference in coverage are available in the annex.	Broadly the same for the manufacturing and construction sectors, however approximately one half of the services sector gross value added (GVA) weights is not covered by the services PMI. Full details of the difference in coverage are available in the annex.
Seasonal adjustment	Current price and chained volume measure estimates are seasonally adjusted using X13 Arima-SEATS.	Businesses are asked to advise IHS Markit of seasonal variations as part of the survey. The diffusion indices are also seasonally adjusted.

Source: Office for National Statistics, IHS Markit Economics

4 . Methodology

Constructing the diffusion indices

For the purposes of this analysis, diffusion indices comparable with the Purchasing Managers' Index (PMI) have been created from a subset of the Monthly Business Survey (MBS) data. A form of standardisation is then applied to both sets of diffusion indices and to official estimates of growth in gross domestic product (GDP) and the services, manufacturing and construction sectors to enable direct comparison of the different indicators. There are four steps to create diffusion indices.

Step 1

The first step in creating the diffusion index is to adjust the Office for National Statistics’s (ONS’s) sector coverage so that it matches, as closely as possible, that of IHS Markit’s. This is done simply by dropping the businesses with the Standard Industrial Classification (SIC) codes excluded from IHS Markit from the Monthly Business Survey (MBS) data. This affects the services sector primarily. It should also be noted that industries that are not included in the MBS are not included in the diffusion index.

Step 2

The turnover for each individual business is then compared with its turnover from the previous period. Where businesses have entered or left the ONS sample, they are not included in the diffusion index. It should be noted that this could introduce a bias over time, as poorly performing business are more likely to go out of business and so be excluded and not replaced in the sample.

The percentage change in turnover compared with the preceding period is calculated and is compared with a user-defined threshold value. The purpose of this threshold value is to capture the fact that in practice the IHS Markit PMI will not be sensitive to small changes in business activity and so will likely report no change even if it has actually slightly increased or decreased.

A plus or minus 5% threshold has been chosen for the analysis in this report. A comparison of the effects of different threshold levels can be found in the appendix in Figures 19 and 20 where it is demonstrated that the choice of threshold level has little effect on the level of correlation found with other series. If the percentage change in turnover for a business is greater than the threshold then it is classified as having increased business activity, if its percentage change falls between the threshold values then it is classified as having the same business activity and if its value is below the threshold value then it is classified as having the reduced business activity.

Step 3

The diffusion index is then calculated using the following formula:

$$I = (1 \times P_U) \; + \; (0.5 \times P_S \;) \; + \; (0 \times P_D)$$

where I is the value of the index, P is the percentage of businesses and the subscripts U, S and D represent the possible directions of business activity compared with the previous month of “up”, “same” and “down”. By multiplying each by the appropriate weighting factor this gives a diffusion index where a value above 50 indicates growth, a value of 50 indicates no change and a value below 50 indicates contraction.

Step 4

Following this the diffusion index is seasonally adjusted, where appropriate, using X13 ARIMA-SEATS software.

For comparison purposes, the PMI, diffusion indices formed from the MBS and official ONS estimates of growth are transformed into standardised units. This is done by calculating the mean and standard deviation for each series and then subtracting the mean from each value in the series before dividing by the standard deviation. This means that all three series will have a mean of 0 and standard deviation of 1, making it easier to determine how consistent they are with each other.

It should be noted that as this process sets the mean of each series to zero, rather than the no change values of 50 for the diffusion indices and 0 for the index growths, values just above and below 0 on the shifted series cannot necessarily be simply interpreted as a prediction of growth or contraction.

IHS Markit and CIPS also publish a composite, all sector PMI, which is constructed by weighting each of the individual sector PMIs by the weight of that sector's contribution to UK GDP. We compare a whole sector MBS diffusion index and GDP growths with this all sector PMI, which we build by weighting each of the three individual sector PMIs as described by IHS Markit.

Measuring correlation between time series

Many of the time series considered in this article are non-stationary, which means that their statistical properties such as their mean, variance or autocorrelation change over time. This makes the traditional method of assessing correlations, the Pearson correlation coefficient, unsuitable as when applied to non-stationary series it can indicate spurious correlations rather than actual relationships between the two series.

An alternative way to measure the level of correlation between two non-stationary time series has been proposed by Gilney Zebende, the detrended cross-correlation analysis (DCCA) coefficient – which is the method adopted in this analysis. The coefficient is found by constructing a profile, or cumulative sum of the time series minus its mean. This profile is then divided up into a number of overlapping boxes of length scale or window size s, which is a property chosen by the analyst. Within each box a linear fit of the time trend is constructed and the residuals from the linear fit and the profile are used to calculate the detrended variance and detrended covariance for each box. The detrended variance and covariance are then averaged over all boxes and these are then used to calculate the correlation coefficient in the normal way. A full derivation of the DCCA coefficient can be found in Ladislav Kristoufek's Measuring correlations between non-stationary series with DCCAcoefficient paper.

The DCCA coefficient is a function of the chosen length scale, s, which allows for the strength of correlation to be tested across different time scales by varying s. The coefficient ranges from negative 1 to 1, with negative 1 indicating perfect negative correlation, 0 indicating no correlation and 1 indicating perfect positive correlation. The minimum time scale considered, or the minimum value of s, must be larger than s = n +2, where n is the order of the polynomial fitted to each box as described by Yuan and others. As we have used a linear fit, n = 1 so we consider only values of s greater than 3 in this article. We also set the maximum value of s = T/5 where T is the length of the time series considered, as is standard in the literature according to Kristoufek (PDF, 449KB).

Finally, to find confidence intervals around zero correlation we generate 10,000 pairs of white noise series with no correlation between them. The DCCA coefficient between each is calculated and together they are used to fit a normal distribution truncated in the range [negative 1, 1], which is then used to find the 95% confidence level for each time series length T and window size s considered.

5 . Example of diffusion indices

The different methodologies of official estimates of output and diffusion indices can lead to very different conclusions about economic performance even when based upon the same underlying data. This can be demonstrated with the short example in Table 2, which shows the output of four fictional businesses in January and February and their corresponding growth rates.

Table 2: Value of work for four fictional businesses and their respective growth rates

	Value of work in January 2019	Value of work in February 2019	Growth rate
Business A	10,000	8,000	-20.0%
Business B	9,500	9,500	0.0%
Business C	13,500	14,250	5.6%
Business D	4,850	5,200	7.2%
Total	37,850	36,950	-2.4%

Source: Office for National Statistics

As Table 2 shows, official estimates based on these four businesses would indicate an overall negative 2.4% growth rate. In contrast, diffusion indices simply register whether output has increased, decreased or stayed the same, so if this data were used to construct a diffusion index it would be interpreted as in Table 3.

Table 3: Diffusion index interpretation of the same data as in Table 2

Direction	Up	Same	Down
Number of companies	2	1	1
Percentage of sample	50%	25%	25%

Source: Office for National Statistics

Applying the formula for diffusion indices shown in the methodology section gives:

$$I = (1 \times 50)\ +\ (0.5 \times 2.5)\ +\ (0 \times 25) = 62.5$$

with a value of 62.5 larger than the no change level of 50 and indicating growth in the sector unlike the official estimates, which show a 2.4% contraction.

This example shows how, even when diffusion indices share the same base data as official estimates of output, the two indicators can give very different conclusions about economic performance. The primary cause of this is that diffusion indices, unlike official estimates, do not account for the magnitude of changes in output in individual respondents, so while there are two businesses, C and D, whose output has increased, this is not enough to compensate for the larger decrease seen in business A. This is an effect that diminishes with increased sample size.

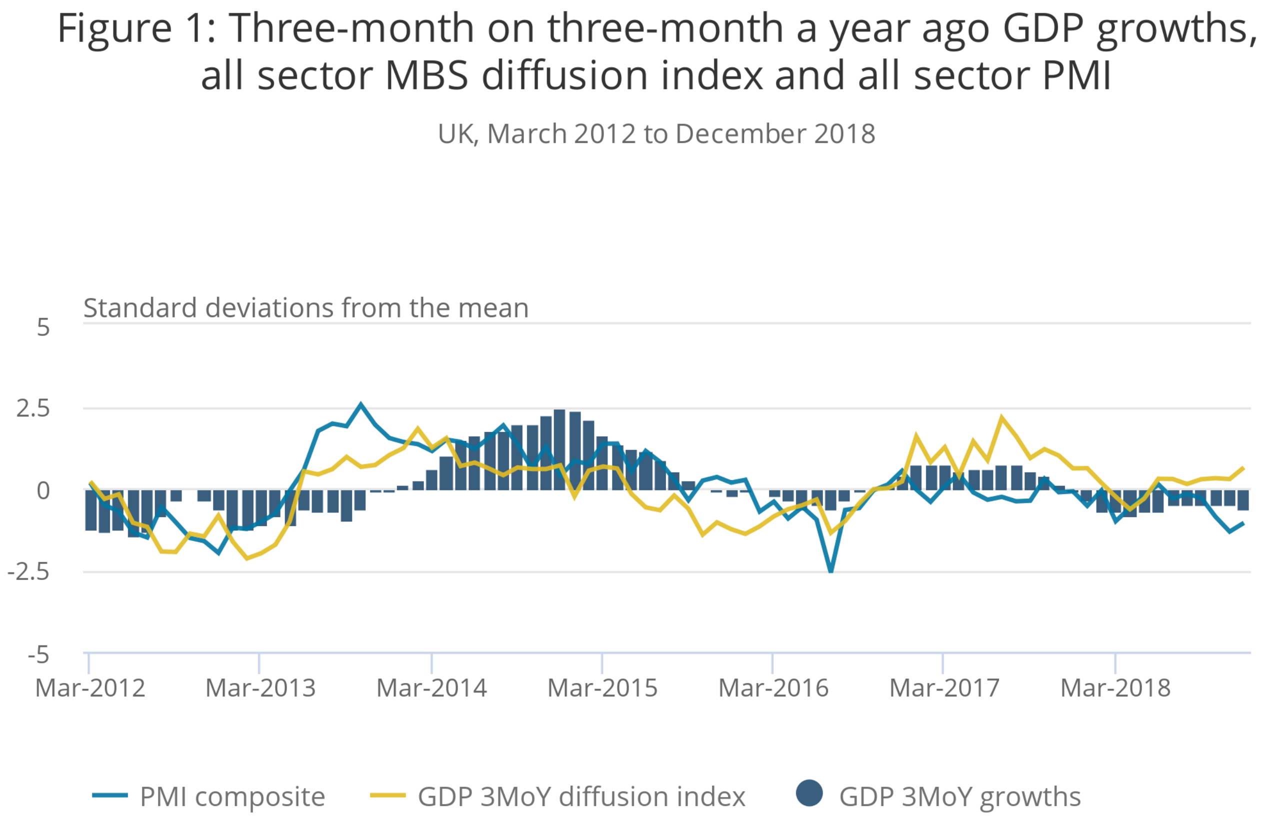
6 . Comparison with ONS three-month on year data

Previous articles comparing Office for National Statistics (ONS) data with IHS Markit's Purchasing Managers' Indices (PMIs) found the strongest relationship between the two to have resulted from comparison of ONS three-months on three-months a year ago data with PMIs.

The figures in this section show the IHS Markit PMIs and diffusion indices constructed from the Monthly Business Survey (MBS) as line graphs compared with official estimates of growth shown as the bar graphs, all in standardised units.

Figure 1: Three-month on three-month a year ago GDP growths, all sector MBS diffusion index and all sector PMI

UK, March 2012 to December 2018



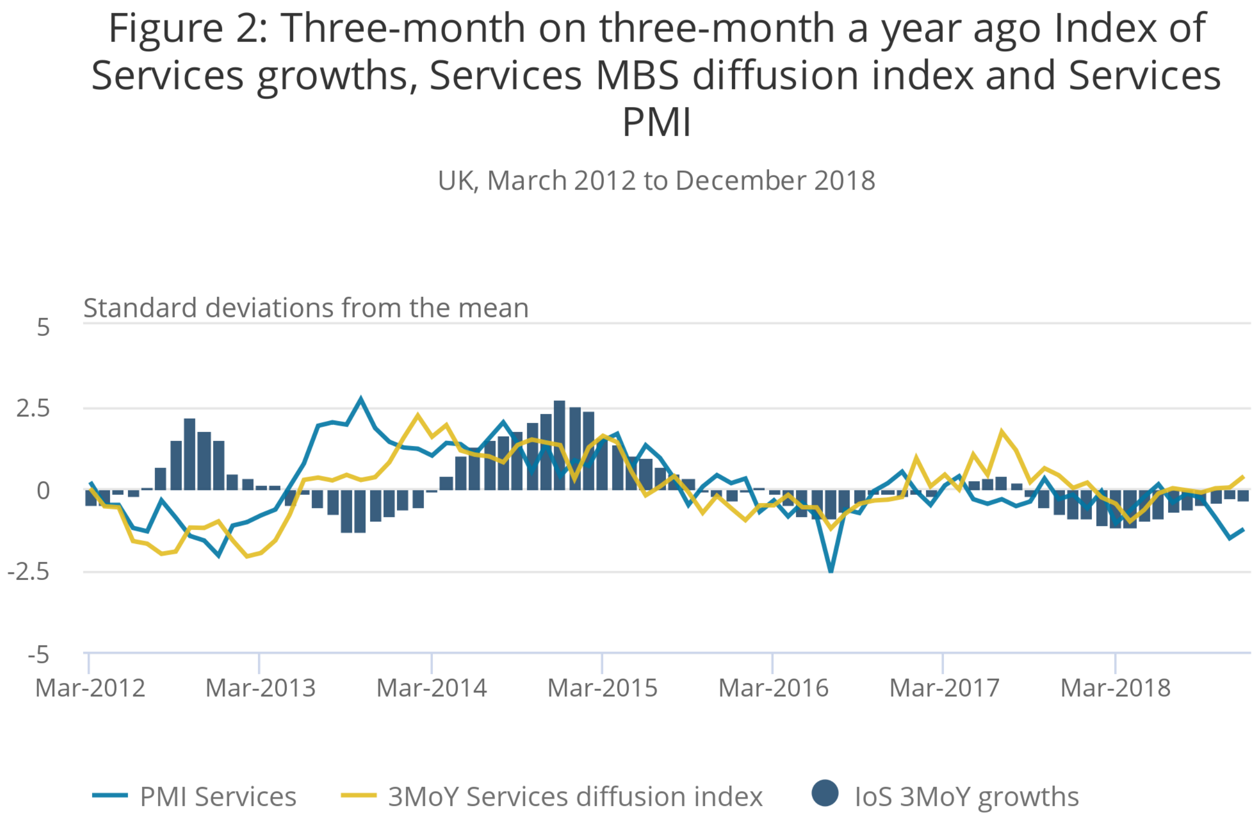
Source: Office for National Statistics, Markit Economics

Notes:

1. gross domestic product (GDP)
2. Monthly Business Survey (MBS)
3. Purchasing Managers' Index (PMI)

Figure 2: Three-month on three-month a year ago Index of Services growths, Services MBS diffusion index and Services PMI

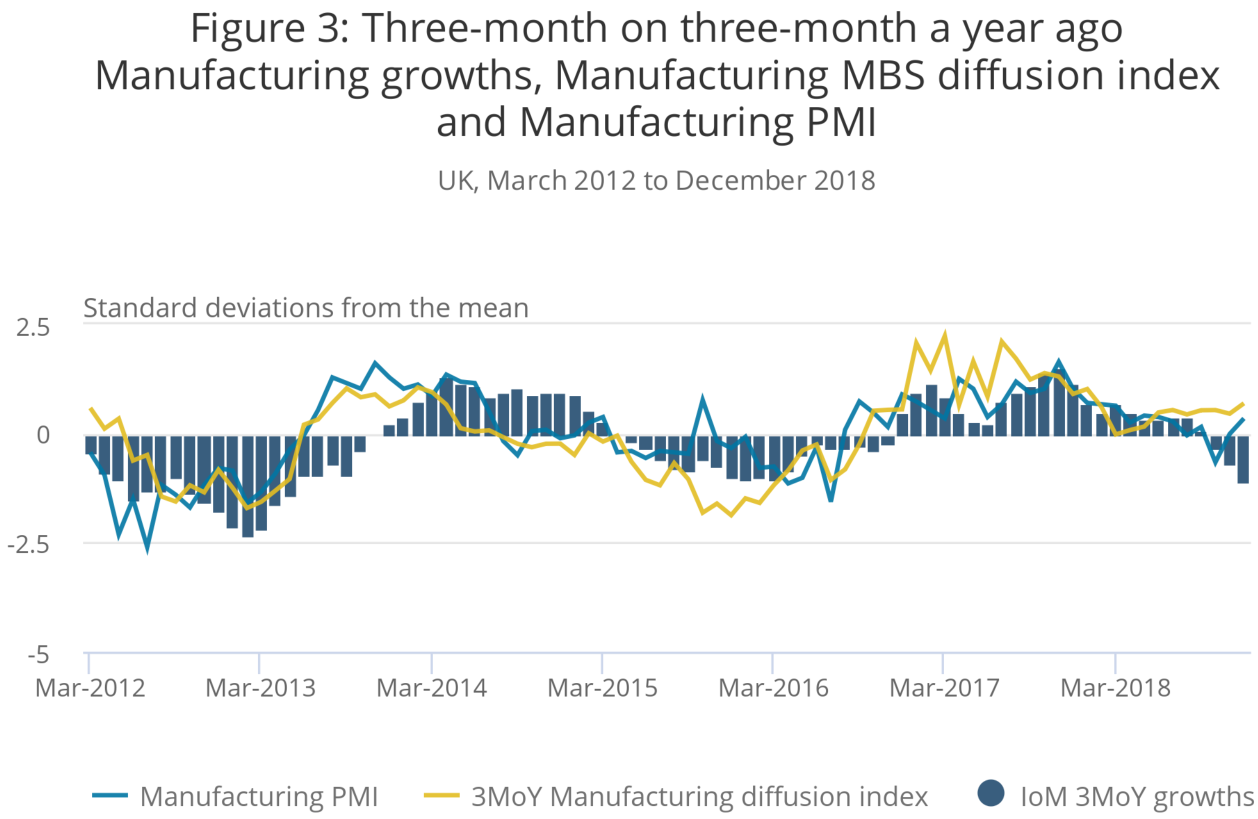
UK, March 2012 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 3: Three-month on three-month a year ago Manufacturing growths, Manufacturing MBS diffusion index and Manufacturing PMI

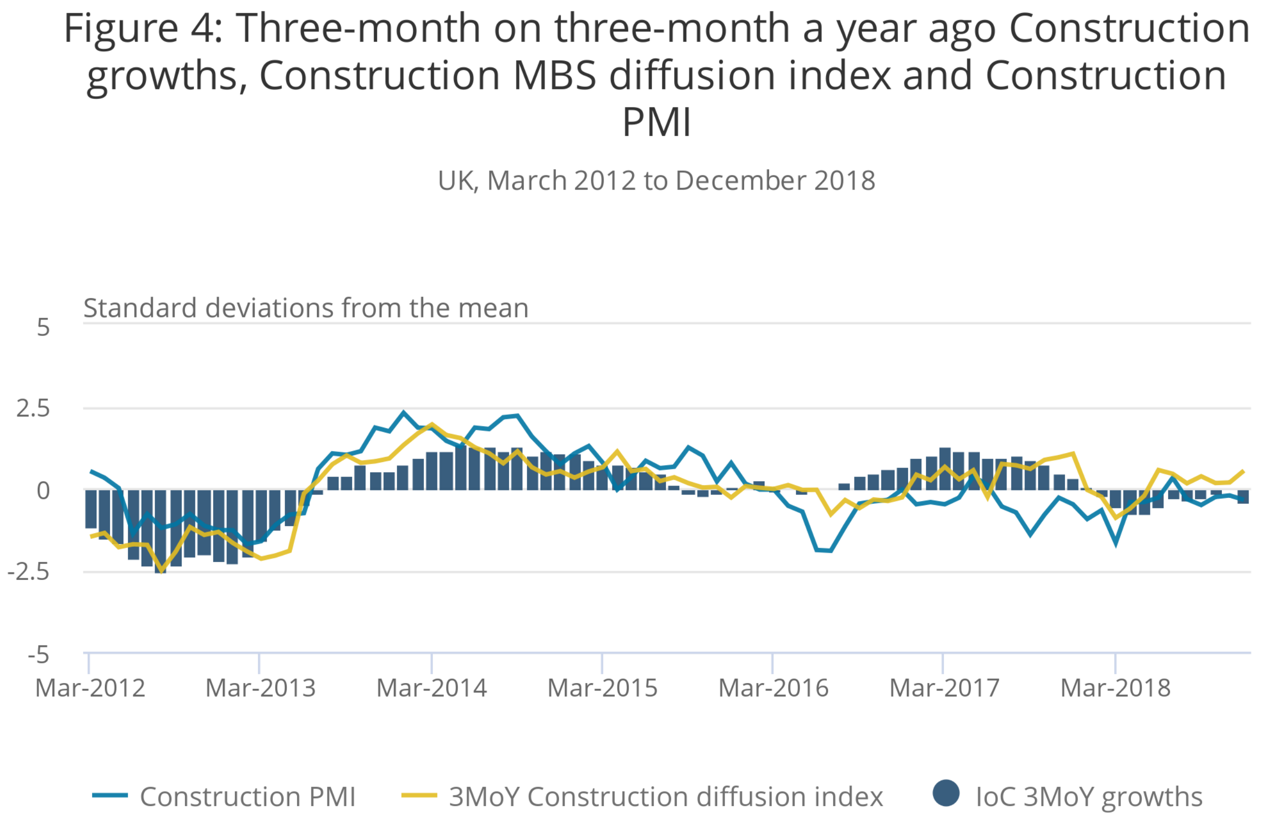
UK, March 2012 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 4: Three-month on three-month a year ago Construction growths, Construction MBS diffusion index and Construction PMI

UK, March 2012 to December 2018



Source: Office for National Statistics, Markit Economics

The match between the three-month on a year ago MBS-based diffusion indices and the PMIs is strong, with the two measures closely tracking each other across the period considered in all three sectors. Unlike comparisons with ONS month-on-month or three-month on three-month data, the two diffusion indices show similar levels of volatility and there are no prolonged periods of discrepancy between the two across any of the sectors.

The relationship between official estimates and the two diffusion indices is also reasonably strong as the three indicators generally move together across the three sectors individually and in the all sector measure. Only one period of sustained discrepancy exists. This is in the services sector from 2012 to 2014 where the two diffusion indices predict a period of below average growth followed by one of above average, while official estimates show exactly the opposite.

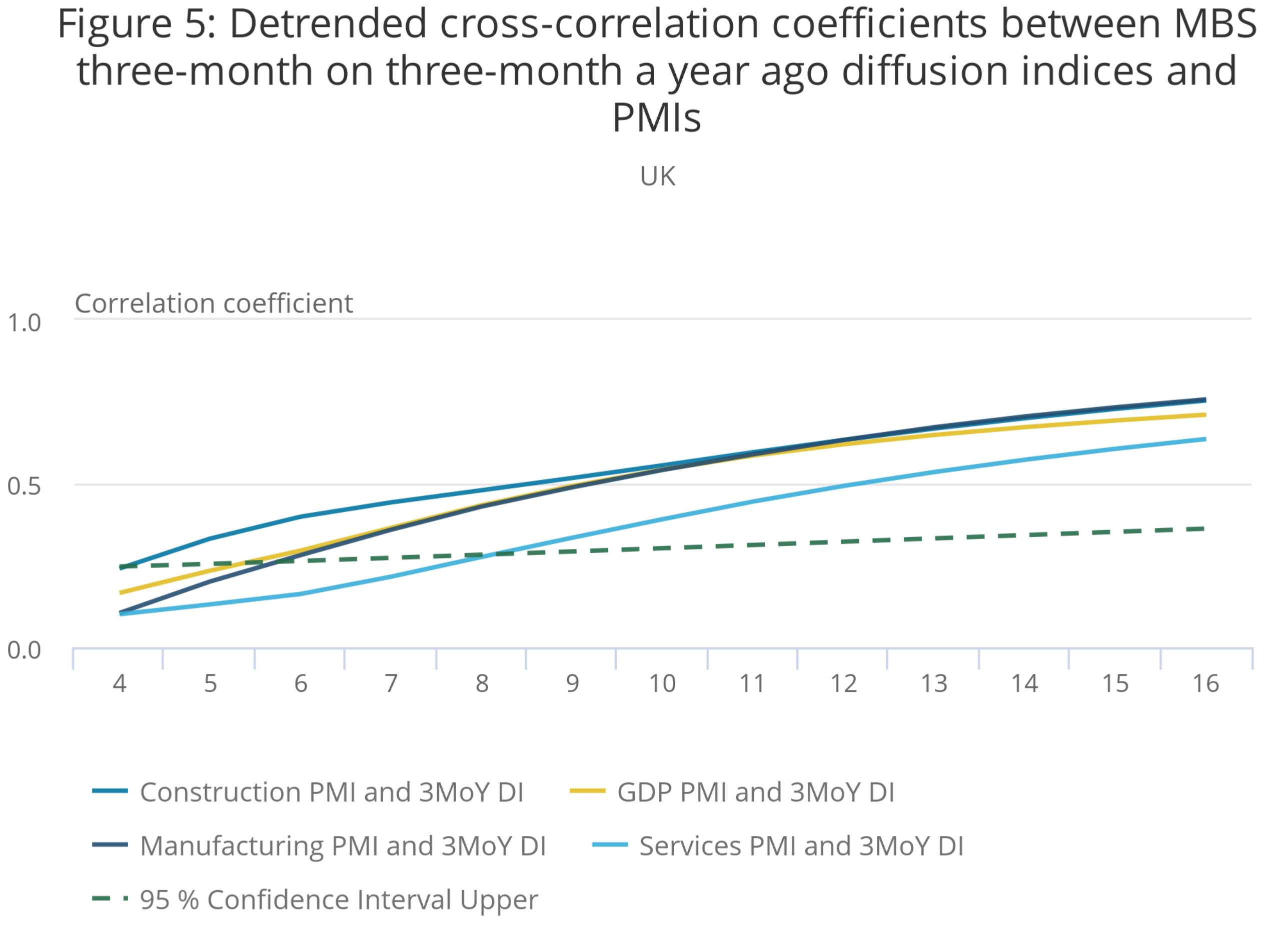
Though there are differences in base data between official estimates and the two diffusion indices because of the IHS Markit PMIs having less coverage of the services sector, this period of discrepancy remains, even when an MBS diffusion index is generated using the full ONS MBS services sector coverage. This indicates that this period of disagreement is not due to differences in sector coverage. It should also be noted that prior vintages of ONS data are generally more closely aligned with the PMIs.

Finally, in all three sectors the PMIs indicate that the economic performance across three sectors just after the Brexit referendum, in July 2016, was substantially weaker than either the MBS-based diffusion index or official estimates predicted. It should be noted that this could be affected by the fact that PMIs ask respondents to compare the situation mid-month with a month ago, rather than looking at the whole month as ONS surveys do. Further work on the performance of all three indicators during economic shocks can be found in the Indicators during economic shocks section.

Figure 5 shows the detrended cross-correlation analysis (DCCA) cross-correlation coefficients between the MBS-based diffusion indices and IHS Markit PMIs for all three sectors. Marked in black on the graph is the 95% confidence level; we take correlations to be statistically significant if the DCCA coefficients are larger than the 95% confidence level, that is if they lie above the black line.

Figure 5: Detrended cross-correlation coefficients between MBS three-month on three-month a year ago diffusion indices and PMIs

UK



Source: Office for National Statistics

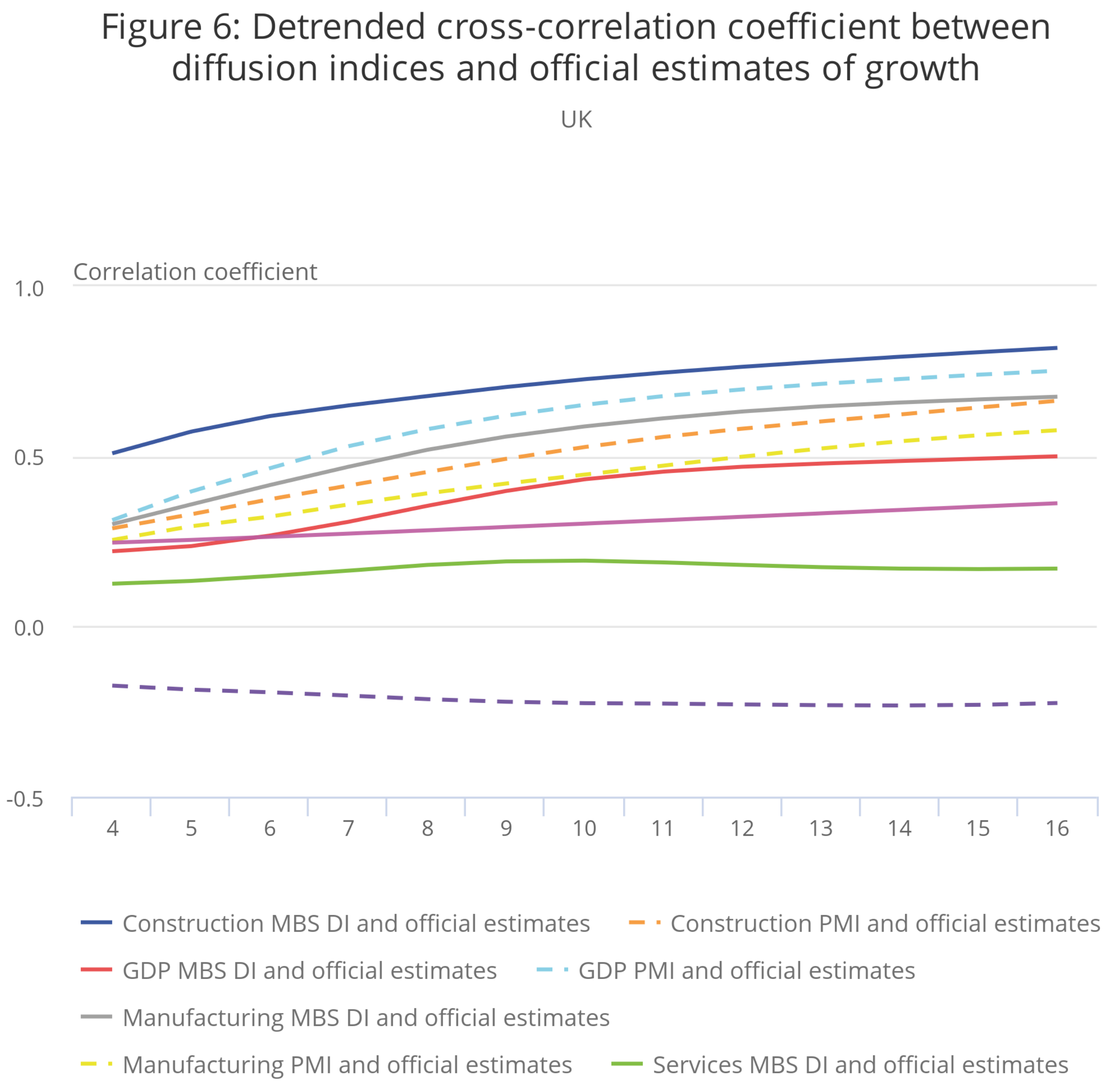
Figure 5 shows that there is a strong, positive correlation between the two diffusion indices across all three sectors and for the UK economy as a whole, with the correlation becoming stronger as longer time periods are considered.

The correlations become significant at the 95% level when sections of the two series longer than five, six and nine months' worth of data are compared for the construction, manufacturing and whole economy, and services sectors respectively. This means that between the manufacturing PMI and manufacturing MBS diffusion index there will be a significant correlation when comparing the data from both over the period from January to June (or any other six-month period or longer), while for the services sector you would need to compare data from January to September (or any other nine-month period or longer) for there to be a significant correlation.

As previously noted, for the construction and manufacturing sectors and the whole economy indicators, the two diffusion indices correspond well with the official estimates of output. However, this is not the case for the services sector, where from early 2012 to 2014 there is a period of discrepancy between the two diffusion indices and official estimates. This difference in congruence between the services sector and the other sections of the economy is clearly shown in the DCCA coefficients in Figure 6. As with Figure 5, correlations are taken to be significant if they lie above the upper 95% confidence bound. A lower 95% confidence bound also exists for negative correlation, this is not shown as no pair of series is significantly negatively correlated at the 95% level.

Figure 6: Detrended cross-correlation coefficient between diffusion indices and official estimates of growth

UK



Source: Office for National Statistics

Figure 6 shows that there is a strong, positive correlation significant at the 95% level between both the MBS-based diffusion indices and PMIs, with ONS official estimates of growths for all window sizes considered for the manufacturing and construction sectors and all sector measure. This can be seen from the fact that the DCCA coefficients for these sectors lie above the upper 95% confidence limit. Significant correlations are also found between growths in gross domestic product (GDP) and both all sector diffusion indices, with PMIs interestingly showing a stronger correlation with official estimates of GDP growth than the MBS-based diffusion index.

However, for the services sector, neither the MBS-based diffusion index nor the PMIs have any significant correlation with headline services three-month on year growths for any window size as can be seen from the fact that their DCCA coefficients lie below the upper 95% confidence interval. This lack of any significant relationship in the services sector may be because there appear to be two distinct periods, from 2012 to 2014, where the diffusion indices and official estimates move in opposite directions and from 2014 onwards, where the diffusion indices and official estimates loosely track each other.

This period of discrepancy and lack of any significant correlation with Index of Services' growths remains even when a diffusion index is constructed using the same data as the Index of Services (without non-MBS industries), rather than the subset used for the previous indices that match sector coverage with IHS Markit and CIPS. This, and the very good match between the ONS diffusion indices and the PMIs precludes differences in the base data from being responsible for this discrepancy and suggests it may be the differences in methodology between diffusion indices generally and the ONS's official estimates of output that are the cause. Regardless, neither the MBS- based diffusion index nor the PMIs are a good indicator for three-months on three-months a year ago movements in official estimates of services output despite the results found for the other sectors.

Overall there is a positive correlation between ONS three-month on three-month a year ago MBS-based diffusion indices and PMIs that is significant at the 95% confidence level across a wide range of medium- to long-term time spans for all three sectors and for the all sector measure of the UK economy. For the construction sector, manufacturing sector and all sector measures, significant correlations also exist between both the MBS-based three-month on year diffusion indices and PMIs with the three-month on year official estimates of growth. However no such relationship exists with services headline growths and either the MBS-based diffusion index or PMI.

The strength of the relationships between ONS three-month on year data and PMIs is stronger than that with either ONS month-on-month or three-month on year data. This suggests that PMI respondents take a wider view of business conditions when replying to PMI surveys than just month-to-month changes, possibly also comparing with performance in the same month a year ago.

7 . Comparison with ONS three-month on three-month data

The graphs for this section are presented in the appendix as Figures 7 to 12. The plots of the three series show that the Monthly Business Survey (MBS)-based diffusion indices remain more volatile than the Purchasing Managers' Indices (PMIs), however, unlike with the month-on-month data the two series do seem to track each other.

The detrended cross-correlation analysis (DCCA) coefficients, shown in Figure 11, support this and indicate that for the services and construction sectors and all sector indices there is a significant correlation between the MBS-based three-month on three-month diffusion indices and the PMIs when periods longer than nine and six months respectively are analysed, though no significant correlation is found between the two indicators for the manufacturing sector.

All four of the MBS-based diffusion indices have significant correlations with official estimates of three-month on three-month growths as can be seen in Figure 12, though for the services sector this is only for periods of 4 to 11 months. Between the PMIs and Office for National Statistics (ONS) official estimates of growth, significant correlations are only found for the manufacturing and all sector measure when periods of six months or longer are considered.

Across all three sectors there are varying relationships between ONS three-month on three-month data and PMIs. Both services and construction show significant correlation between the MBS-based diffusion index and PMIs but no relationship between PMIs and official estimates of growth. In contrast, manufacturing has no significant correlation between its diffusion index and PMIs but is the only sector with significant correlation between PMIs and official estimates of growth. The all sector PMI is the only one to show significant correlation with both the MBS-based diffusion index and official estimates of growth.

8 . Comparison with ONS month-on-month data

The graphs for this section are presented in the appendix as Figures 13 to 18. The plots of the three series show that across all three sectors, both the month-on-month headline growths and Monthly Business Survey (MBS)-based diffusion indices are substantially more volatile than the Purchasing Managers' Indices (PMIs) and do not indicate the sustained periods of above and below average growth seen in the PMIs.

The detrended cross-correlation analysis (DCCA) coefficients, shown in Figure 17, indicate that there is no significant correlation between the MBS-based month-on-month diffusion indices and the IHS Markit PMIs, with construction only above the confidence threshold when periods of four months are considered and dropping below for all longer periods. As this correlation is not sustained across multiple window sizes we do not take this as evidence of a significant correlation between the two series.

Between the diffusion indices and official estimates of month-on-month growths, seen in Figure 18, significant correlations are found between the MBS-based month-on-month services, construction and all sector diffusion indices and their respective official estimates of growths. There is no significant correlation between any of the IHS Markit PMIs and any of the Office for National Statistics's (ONS's) official estimates of month-on-month growths. Overall, there is no significant relationship between official estimates of month-on-month growth and PMIs or between diffusion indices constructed from MBS data and PMIs.

9 . Summary tables

The following summary tables show whether significant, sustained correlation was found between the Markit Purchasing Managers' Indices (PMIs) and all Office for National Statistics (ONS) series and between official estimates of growth and both Markit PMIs and Monthly Business Survey (MBS) diffusion indices. To avoid counting spurious correlations we define two series as having sustained correlation if they have significant correlation at the 95% level across at least three or more consecutive interval lengths.

Table 4: Where sustained correlation significant at the 95% confidence level was found between the Markit PMIs with the MBS diffusion indices and official estimates of growth

	All sector PMI	**Services PMI**	**Manufacturing PMI**	**Construction PMI**
MBS month on month diffusion indices	No	No	No	No
ONS month on month growths	No	No	No	No
MBS three-months on three-months a year ago diffusion indices	Yes	Yes	Yes	Yes
ONS three-months on three-months a year ago growths	Yes	No	Yes	Yes
MBS three-month on three-month diffusion indices	Yes	Yes	No	Yes
ONS three-month on three-month growths	Yes	No	Yes	No

Source: Office for National Statistics

Table 5: Where sustained correlation significant at the 95% confidence level was found between the official estimates of growth with the MBS diffusion indices and the Markit PMIs

	Three-months on three-months a year ago growths	Three-months on three-month growths	Month on month growths
All sector MBS based diffusion indices	Yes	Yes	No
Services MBS based diffusion indices	No	Yes	Yes
Manufacturing MBS based diffusion indices	Yes	Yes	No
Construction MBS based diffusion indices	Yes	Yes	Yes
All sector PMI	Yes	Yes	No
Services PMI	No	No	No
Manufacturing PMI	Yes	Yes	No
Construction PMI	Yes	No	No

Source: Office for National Statistics

Notes

1. 1. Purchasing Managers' Index (PMI) Back to table
2. 2. Monthly Business Survey (MBS) Back to table
3. Back to table

10 . Indicators during economic shocks

Previous work comparing official estimates of growth with Purchasing Managers' Indices (PMIs) has noted that: "with unexpected and prolonged shocks, the IHS Markit/CIPS trend exaggerates the magnitude; but with expected /short 'shocks', IHS Markit/CIPS under-estimates". This work did not include the construction of a diffusion index from Office for National Statistics (ONS) Monthly Business Survey (MBS) data and so the effects of sudden shocks on MBS diffusion indices could not be investigated.

Two possible examples of economic shocks have been identified. The first was in June 2012 when the Queen's Diamond Jubilee meant that there were extra holidays; this can be considered an example of an expected shock as the disruption caused by the Jubilee was known in advance.

The second was the EU referendum result on 23 June 2016; previous HM Treasury analysis found that a vote to leave would "cause a profound economic shock" and so this is taken as an example of an unexpected shock. Because of the fact the referendum took place late in June, we look at July 2016 to see its effects.

Though no significant correlation was found between either official estimates of month-on-month growth and PMIs, or month-on-month diffusion indices constructed from MBS data and PMIs, it is still instructive to look at how both indicators react to sudden shocks. This can be done by looking at Table 6, where the value of each indicator in July 2016 can be found in units of standard deviations from the mean.

Table 6: PMI and month-on-month ONS series values for July 2016 in units of standard deviations from the mean

Sector	PMI (SD)	MoM ONS diffusion index (SD)	MoM ONS headline growths (SD)
Services	-2.6	-1.1	0.27
Manufacturing	-1.6	-1.3	-0.58
Construction	-1.9	-1.5	0.62
GDP (all sector)	-2.6	-1.1	0.32

Source: Office for National Statistics, Markit Economics

Both diffusion indicators indicate that July 2016 was a significantly below average month, with all eight readings more than one standard deviation below the mean. The PMIs estimates are further below average than the MBS-based diffusion index for all three sectors of the UK economy, with the difference between the two estimations for services and GDP substantially larger than for the other two sectors.

In contrast, official estimates indicate that July 2016 was an average month for output, with all three sectors growths' within one standard deviation of the mean. These results corroborate previous findings that, with unexpected shocks, PMIs tend to exaggerate the effect relative to official estimates but show that the same is also true of the MBS-based diffusion index. This may indicate that the effect of the shock was more diffuse and had a small effect on many firms, or that it impacted relatively more upon smaller firms. As the magnitude of any decrease in performance are not accounted for by diffusion indices, these effects could lead them to overestimate the impact relative to official estimates.

The performance of the three indicators during the expected shock of the Queen's Diamond Jubilee was very different. Both diffusion indices estimate that June 2012 was a substantially below average month, however, aside from the MBS-based construction diffusion index, neither comes close to the official estimates of how far below average the month was.

Table 7: PMI and month-on-month ONS series values for June 2012 in units of standard deviations from the mean

Sector	PMI (SD)	MoM ONS diffusion index (SD)	MoM ONS headline growths (SD)
Services	-1.2	-1.6	-3.7
Manufacturing	-1.5	-1.9	-2.9
Construction	-1.4	-2.7	-2.8
GDP (all sector)	-1.4	-1.2	-4.2

Source: Office for National Statistics, Markit Economics

This supports previous findings that PMIs tend to underestimate the effect of expected shocks relative to official estimates but finds that MBS-based diffusion indices also underestimate the effect of shocks, even when based upon the same data as official estimates.

A possible explanation for this is that larger firms were affected more by this shock than smaller firms, as the relative sizes are not accounted for by diffusion indices. In the case of PMIs it could also be the case that firms make allowances for the unusual trading pattern. That the MBS-based construction diffusion index is much lower and closer to official estimates than the other two sectors suggests that the effect in the construction sector was more diffuse than elsewhere.

The behaviour of the indicators during these two shocks is consistent with what was previously found. PMIs overestimate the effect of unexpected shocks and underestimate the effects of expected ones relative to official estimates. However, it is also found that diffusion indices formed from the same data as official estimates have the same tendencies, though to a lesser degree. This suggests that the tendency for the two indicators to under and overestimate relative to official estimates is a consequence of the properties of diffusion indices, particularly in the case of the MBS-based ONS diffusion indices where, unlike PMIs, businesses are not weighted by size.

11 . Conclusion

Statistically significant relationships have been found between IHS Markit’s Purchasing Managers’ Indices (PMIs) and Office for National Statistics (ONS) data.

By comparing PMIs with a diffusion index calculated using Monthly Business Survey (MBS) data based on three-month on three-month a year ago changes, significant and positive correlations were found between the indicators for all three individual sectors and for the whole economy diffusion indices across time periods of a few months or longer.

Significant correlation was also found between both the MBS-based diffusion indices and PMIs with official estimates of growth for the manufacturing and construction sectors and the whole economy measures, but not for services where the two diffusion indices do not closely track official estimates of output.

Relationships were also found to exist between three-month on three-month MBS-based diffusion indices and official estimates of three-month on three-month growth with PMIs. For the services and construction sectors and all sector measure, a significant positive correlation was found between the MBS-based diffusion index and the PMIs. While this was not found for the manufacturing sector, the manufacturing PMI and all sector PMI did show significant, sustained correlation with ONS official estimates of three-month on three-month growths. The utility of diffusion indices as predictors of three-month on three-month changes is also illustrated by the fact that all four MBS-based diffusion indices are significantly correlated with official estimates of growth over a range of time periods.

No significant relationships were found to exist between the PMIs and either official estimates of month-on-month growth or the month-on-month MBS-based diffusion indices. Both the ONS MBS-based diffusion indices and official estimates of growth were more volatile than the PMIs and no significant correlation was found between either and the PMIs.

Statistically significant correlations were found between the services, construction and all sector MBS-based diffusion indices and official estimates of month-on-month growths, though these correlations were substantially weaker than those found in the three-month on three-month a year ago.

The limitations of diffusion indices for predicting the more volatile month-on-month changes in output is illustrated by the lack of any significant correlation between the manufacturing diffusion index and growths, despite the two measures being based upon the same underlying data. On the evidence of this analysis, the IHS Markit PMIs cannot be taken as an early indicator for official estimates of month-to-month changes in output.

Finally, previous findings that the IHS Markit PMIs overestimate the effect of sudden economic shocks and underestimate the effect of shocks known in advance relative to official estimates of output were corroborated, though the sample size for this is small. However, the role of PMI responder sentiment as a potential cause of this is called into question by the fact that the MBS-based diffusion indices exhibit similar over and underestimation relative to official outputs. That these effects occur even when the diffusion index and official estimates share base data suggests that these effects may arise from limitations with diffusion indices, such as the fact that the magnitude of changes for individual businesses is not used to form the indicator.

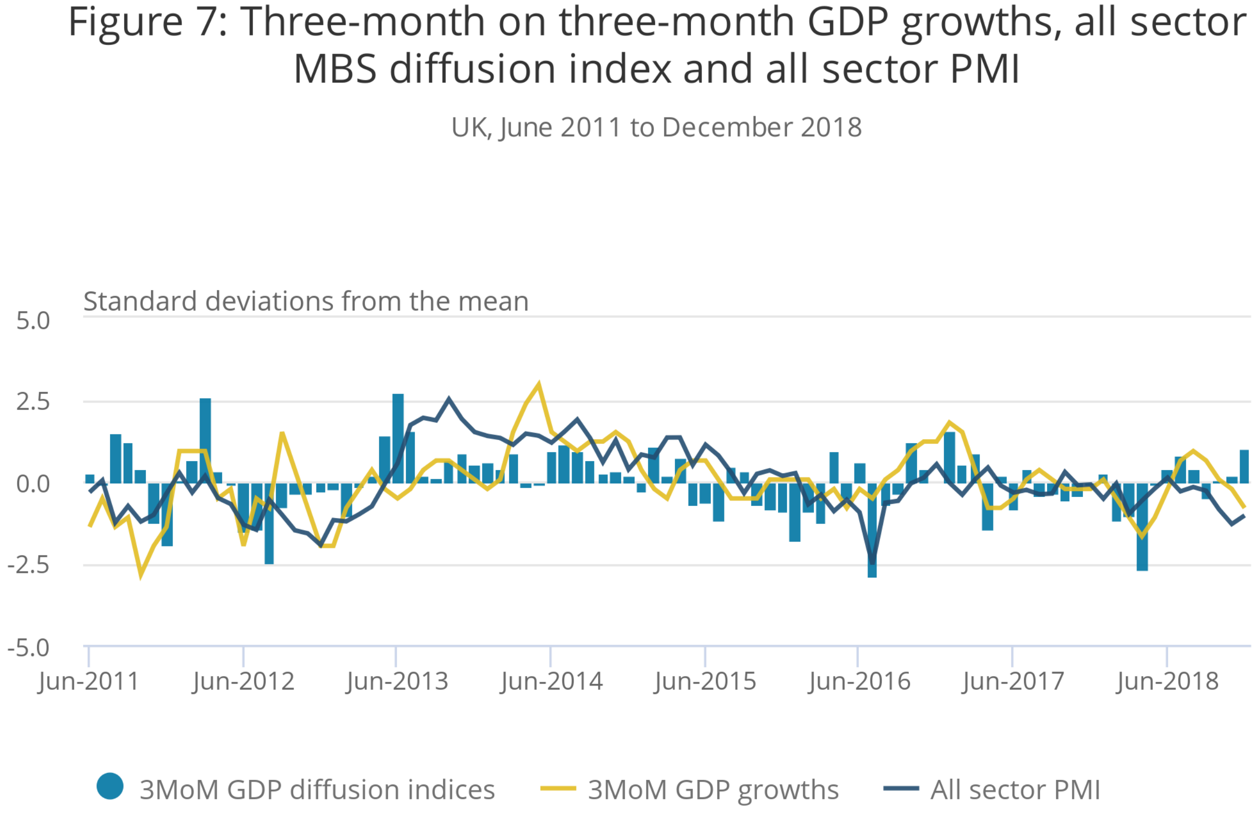
12 . Authors

Henry Duquemin,Mark Stephens, Office for National Statistics.

13 . Appendix

Figure 7: Three-month on three-month GDP growths, all sector MBS diffusion index and all sector PMI

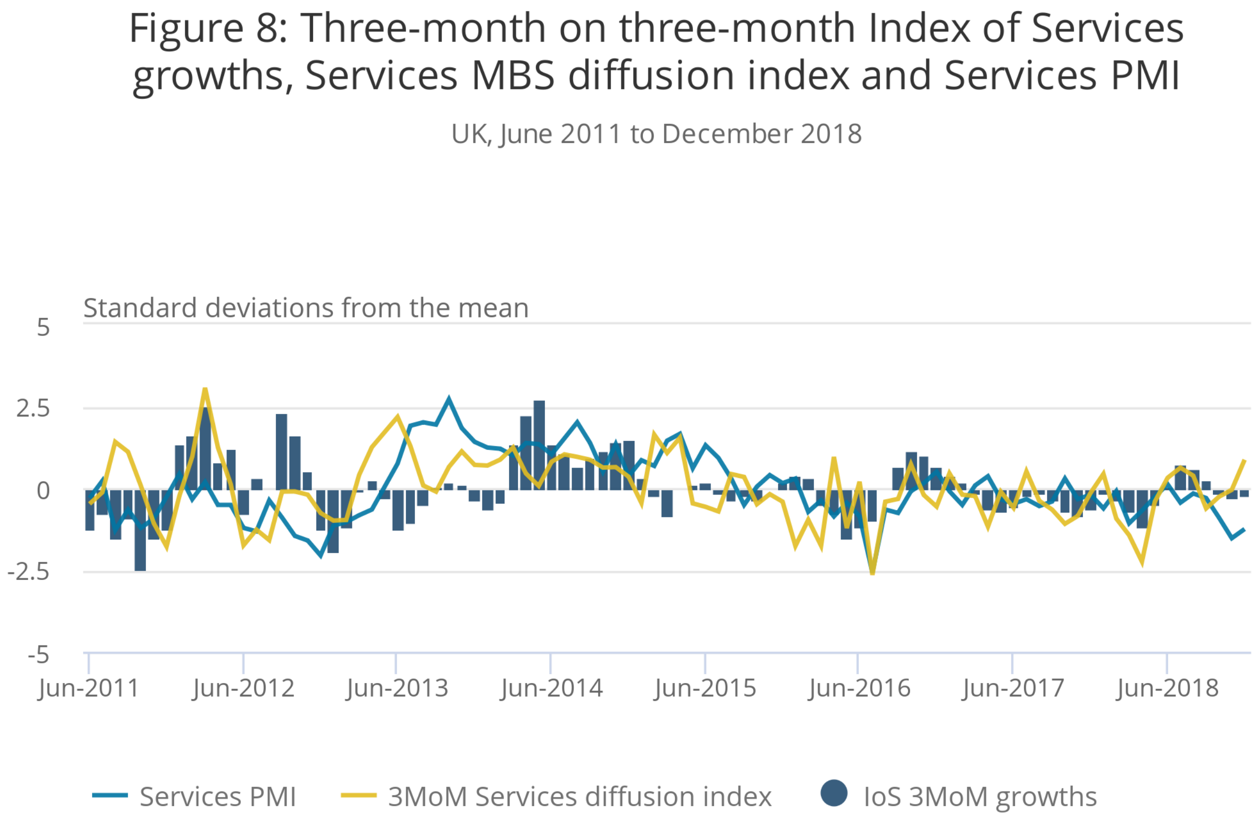
UK, June 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 8: Three-month on three-month Index of Services growths, Services MBS diffusion index and Services PMI

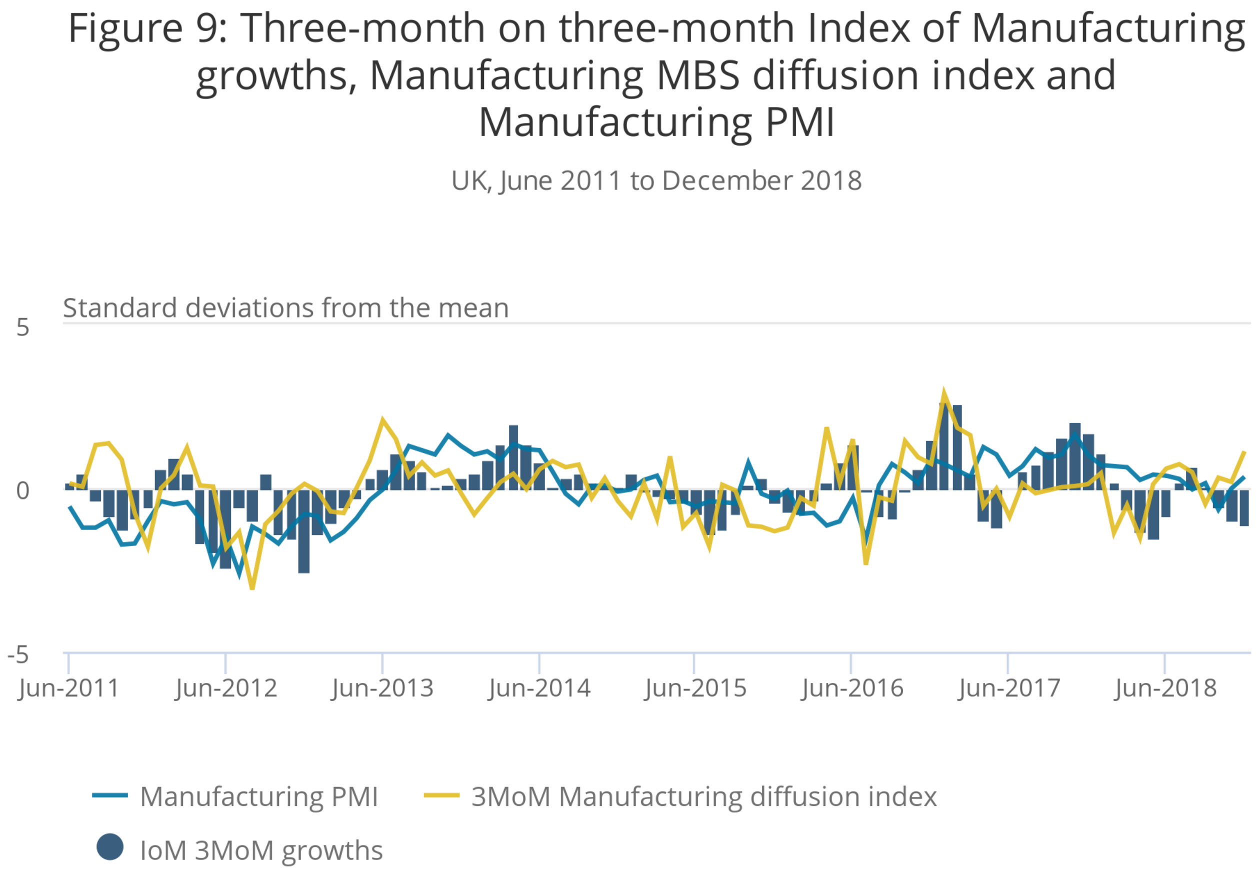
UK, June 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 9: Three-month on three-month Index of Manufacturing growths, Manufacturing MBS diffusion index and Manufacturing PMI

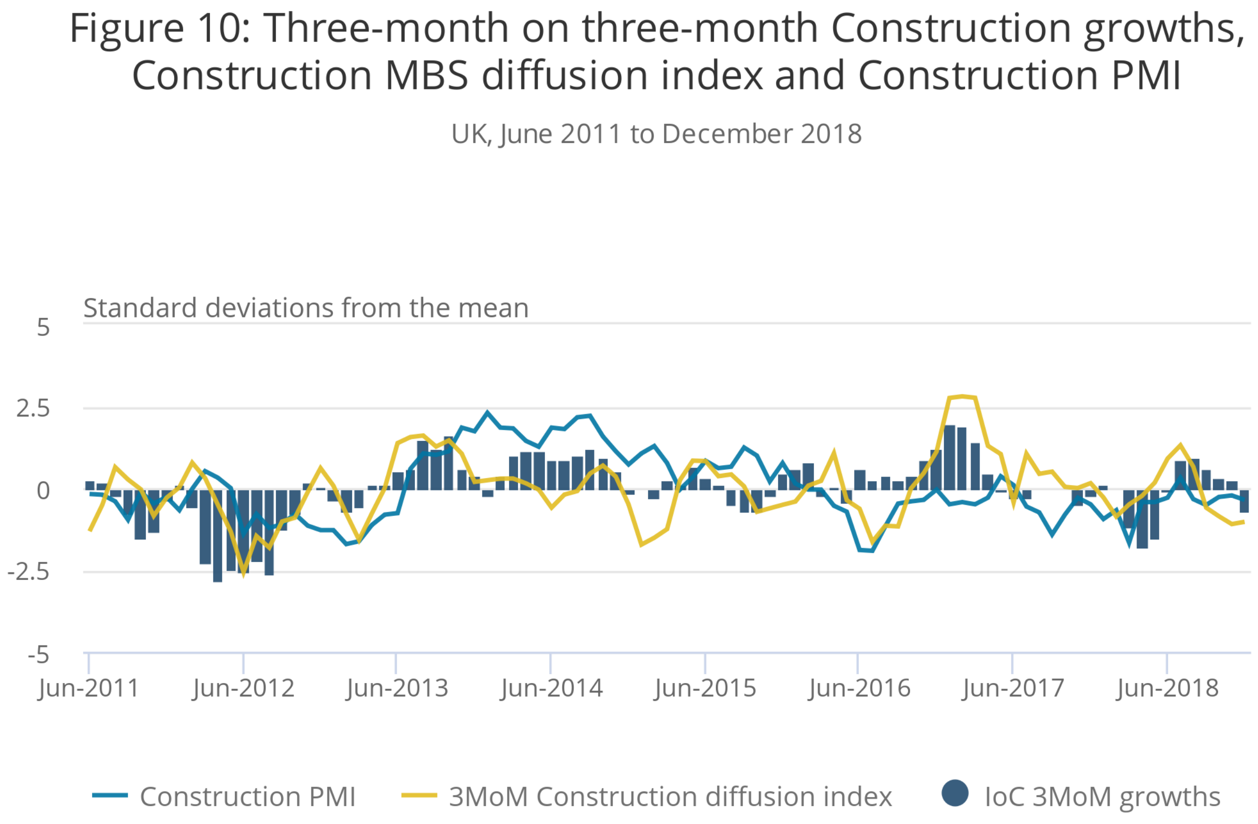
UK, June 2011 to December 2018



Source: Office for National Statistics, Markit Economics

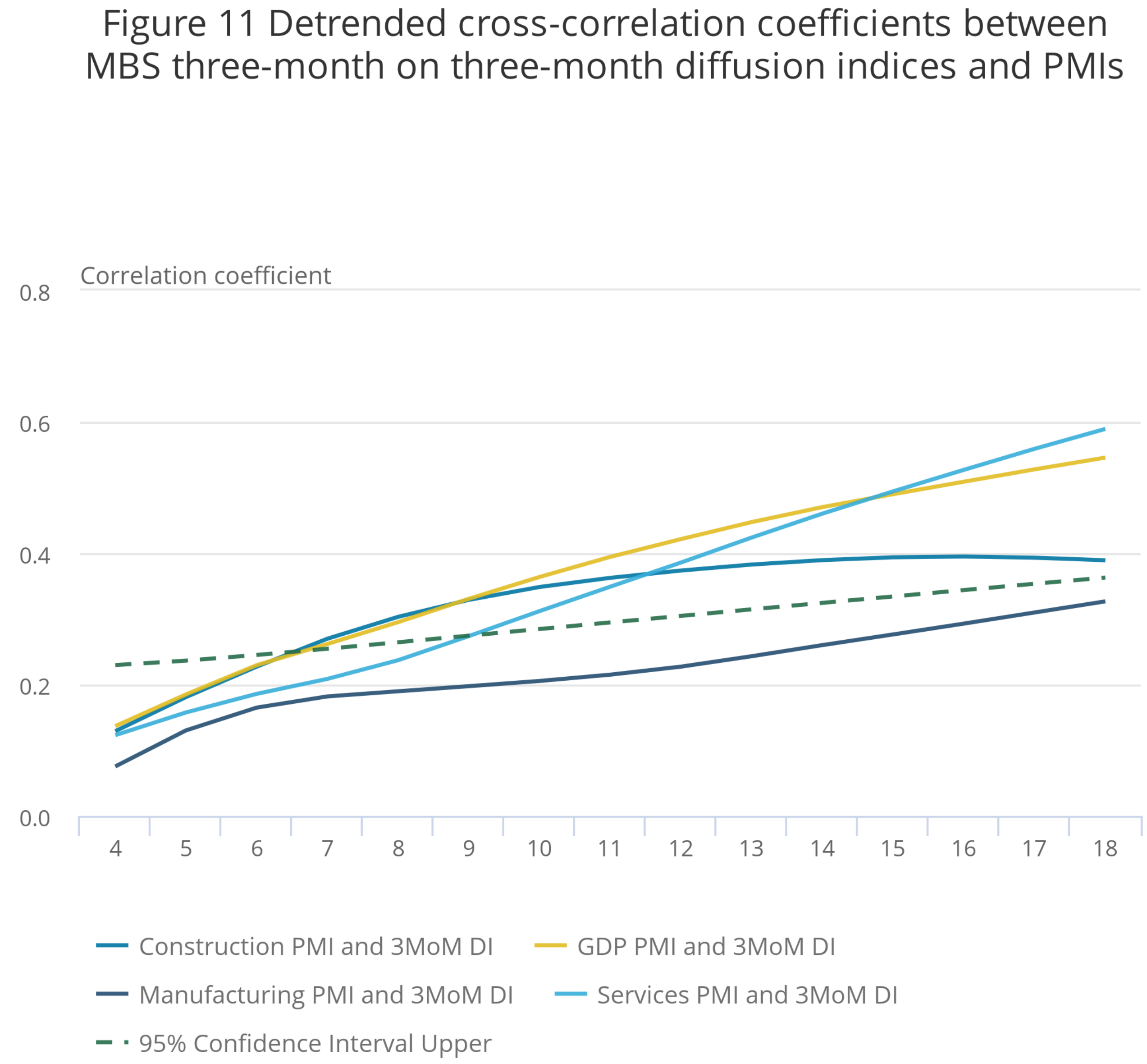
Figure 10: Three-month on three-month Construction growths, Construction MBS diffusion index and Construction PMI

UK, June 2011 to December 2018



Source: Office for National Statistics, Markit Economics

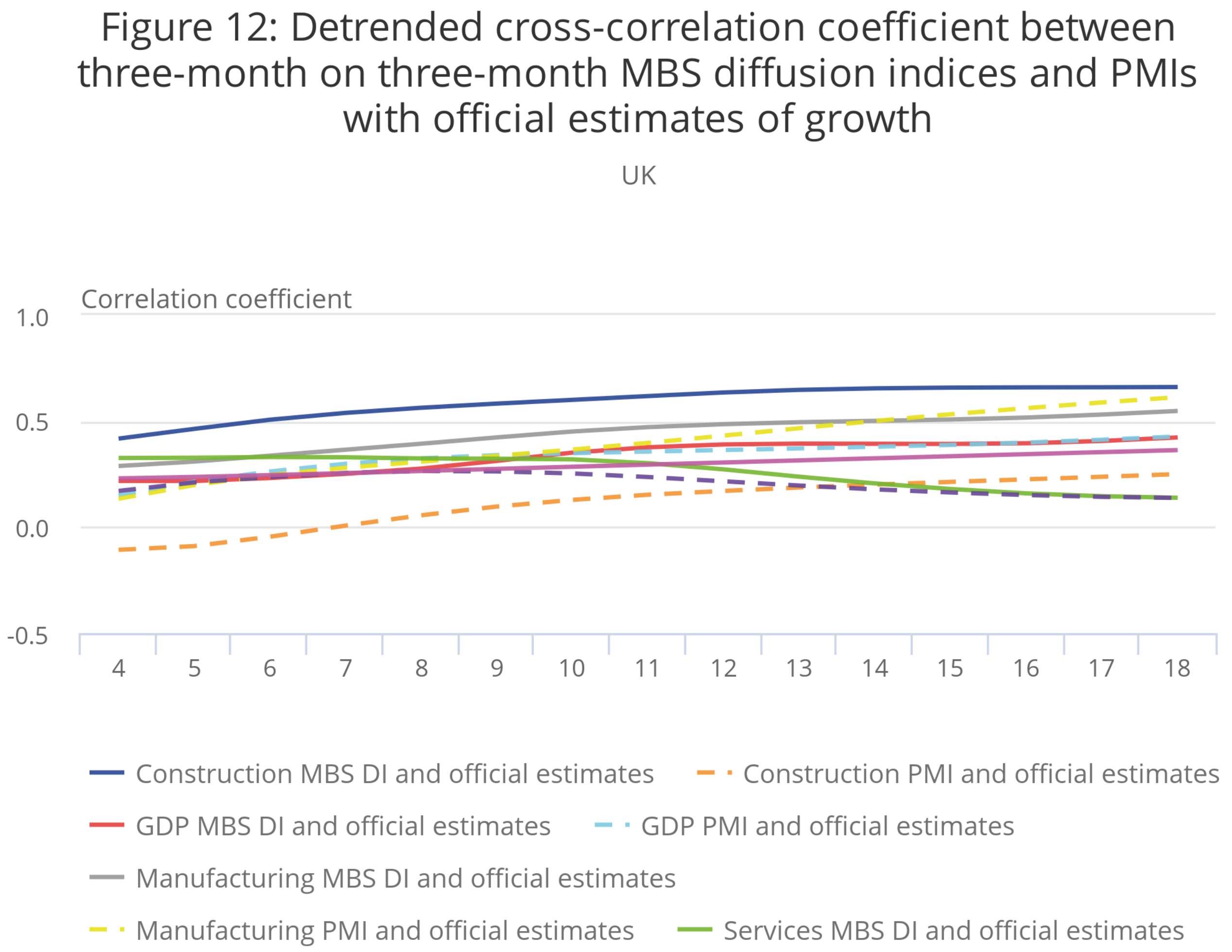
Figure 11 Detrended cross-correlation coefficients between MBS three-month on three-month diffusion indices and PMIs



Source: Office for National Statistics

Figure 12: Detrended cross-correlation coefficient between three-month on three-month MBS diffusion indices and PMIs with official estimates of growth

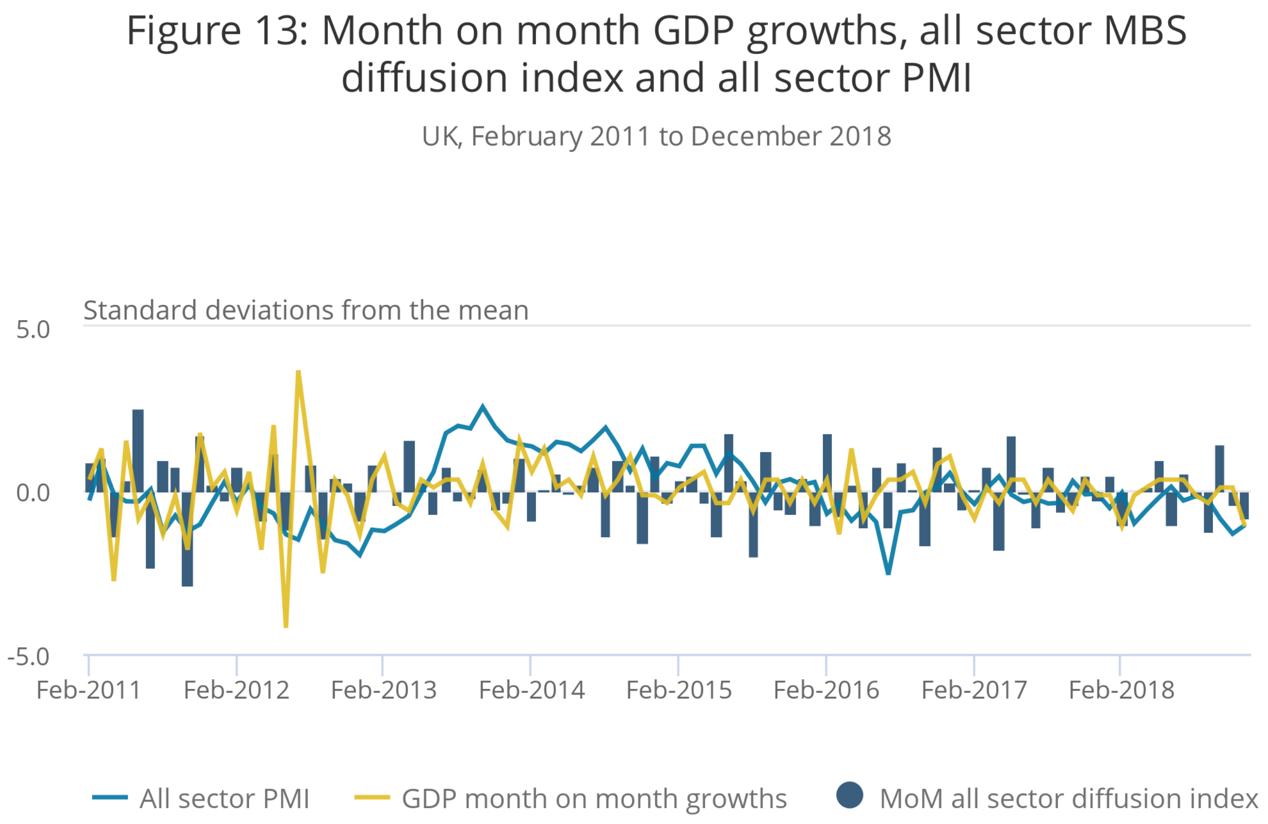
UK



Source: Office for National Statistics

Figure 13: Month on month GDP growths, all sector MBS diffusion index and all sector PMI

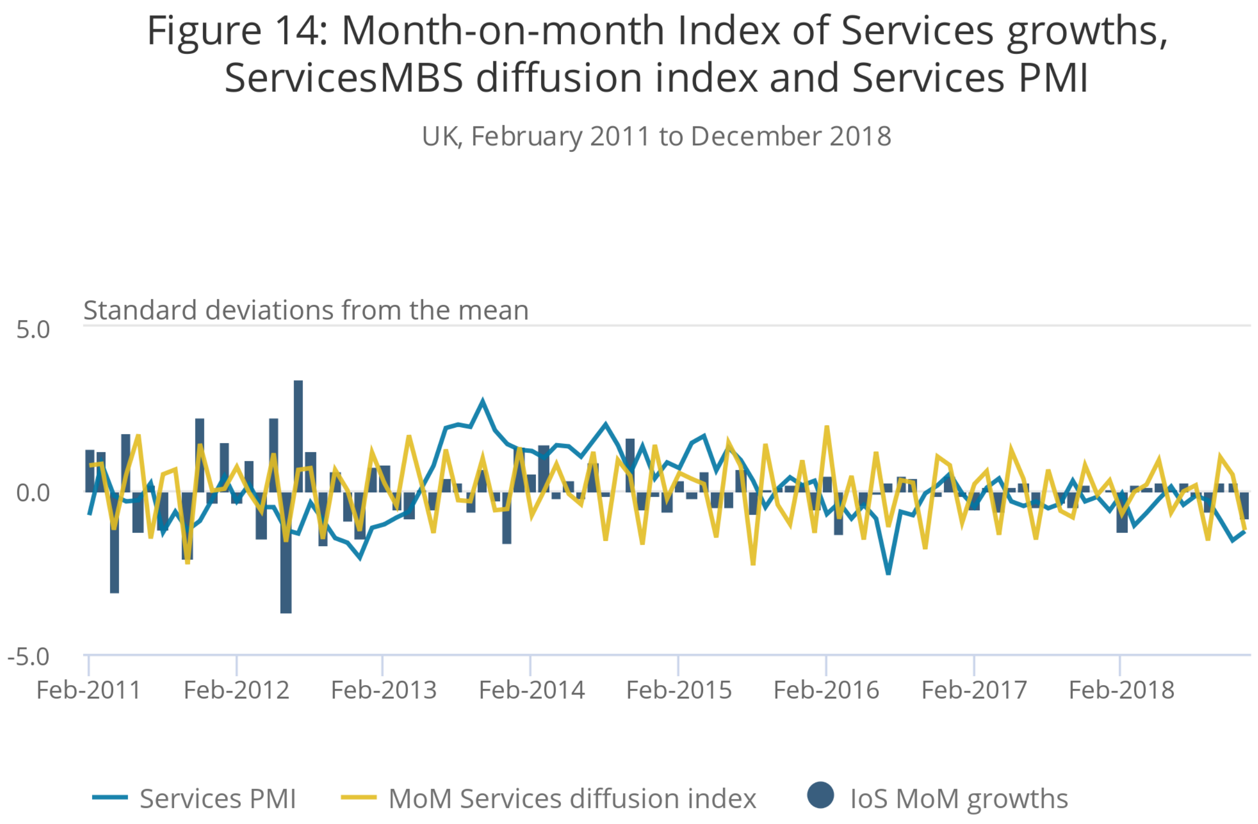
UK, February 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 14: Month-on-month Index of Services growths, ServicesMBS diffusion index and Services PMI

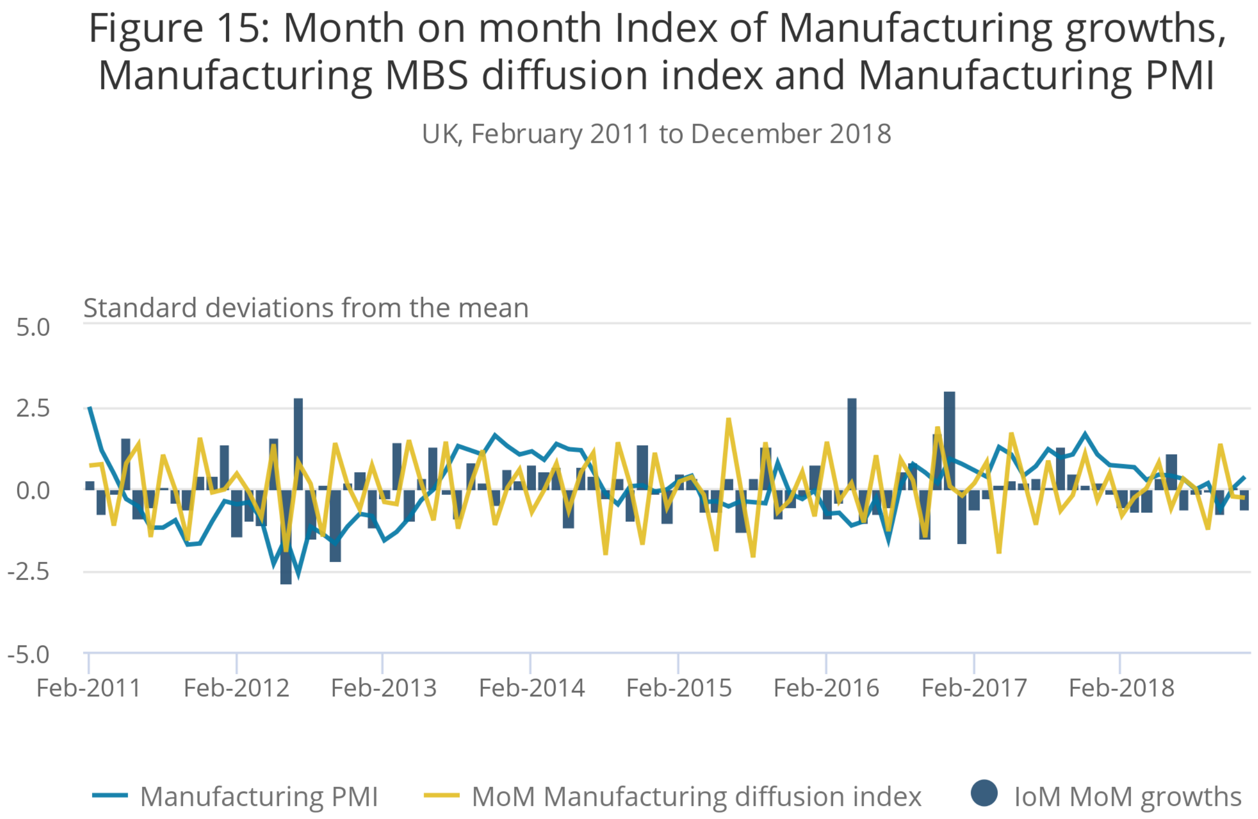
UK, February 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 15: Month on month Index of Manufacturing growths, Manufacturing MBS diffusion index and Manufacturing PMI

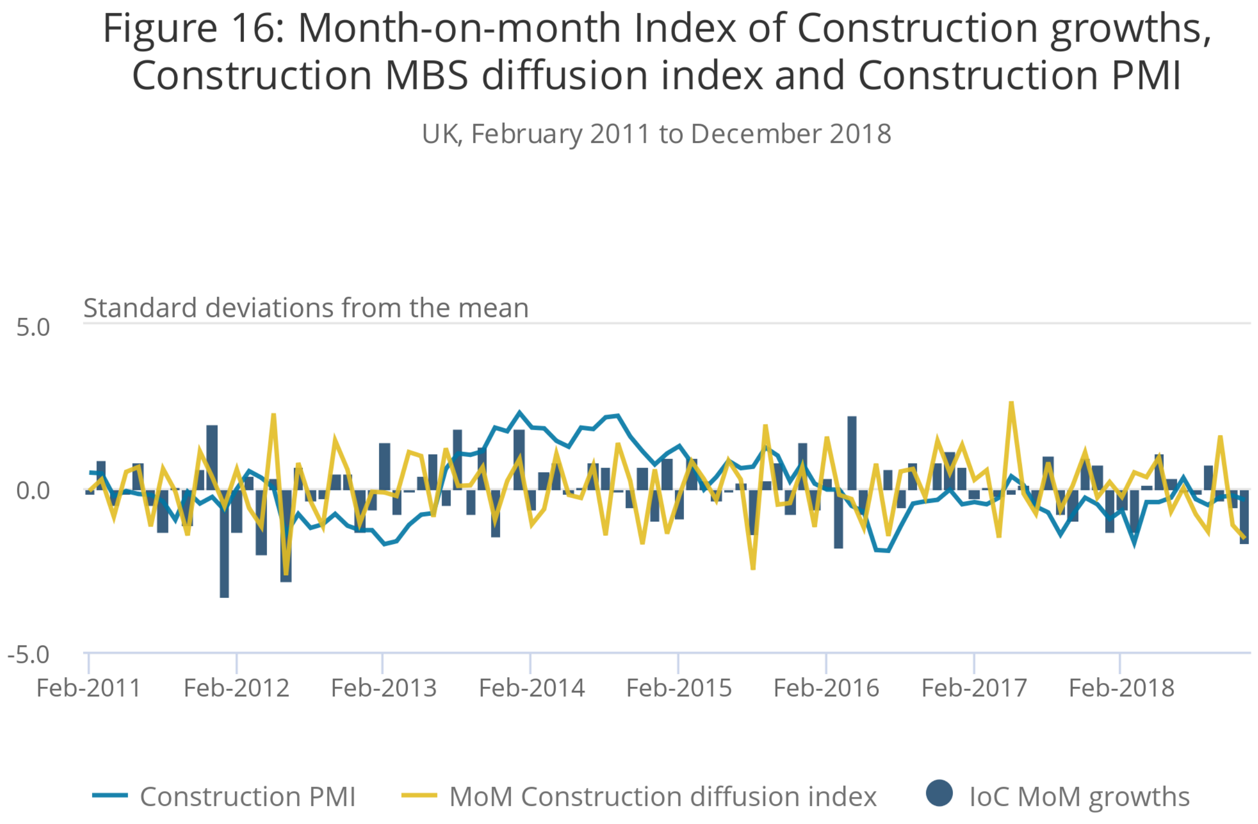
UK, February 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 16: Month-on-month Index of Construction growths, Construction MBS diffusion index and Construction PMI

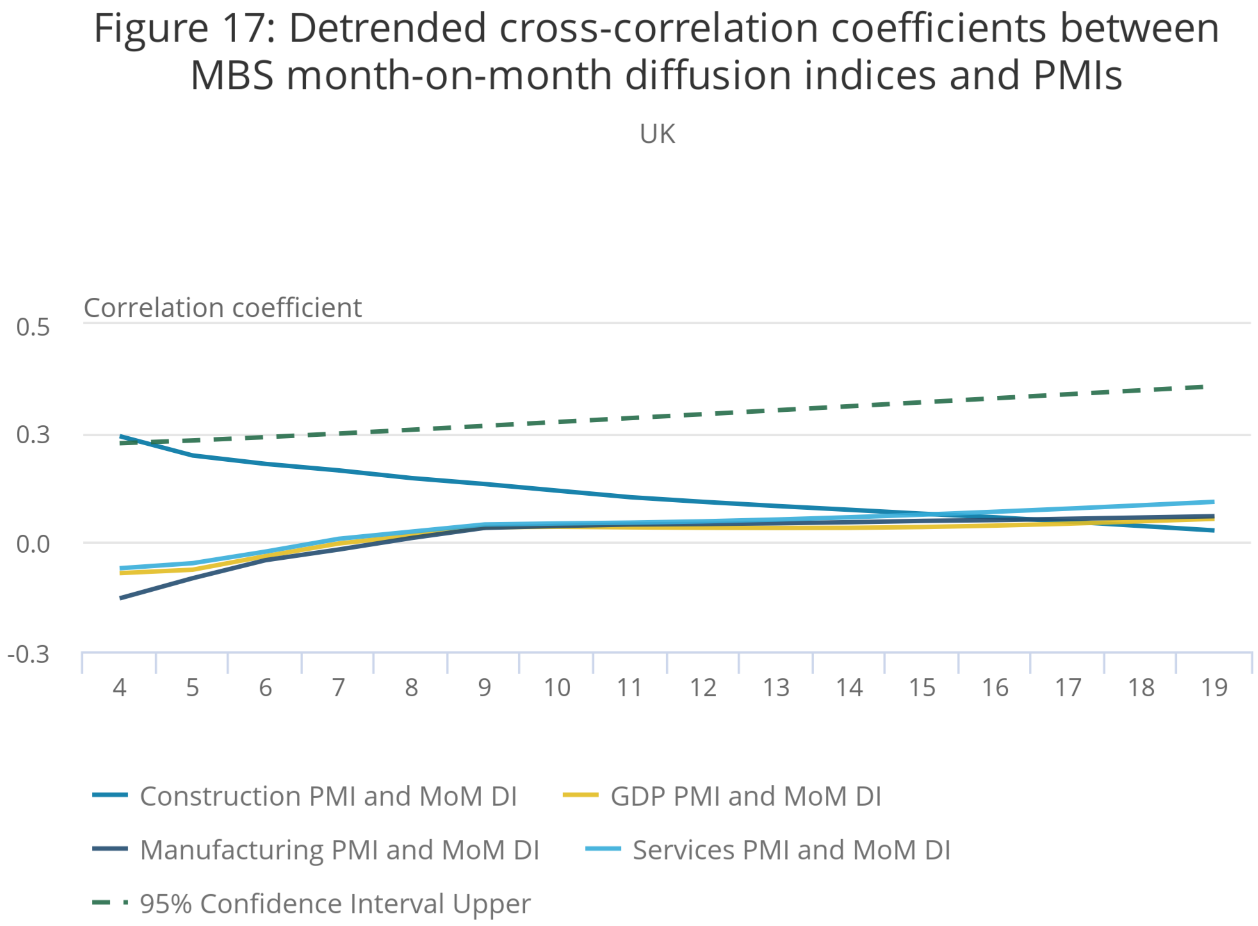
UK, February 2011 to December 2018



Source: Office for National Statistics, Markit Economics

Figure 17: Detrended cross-correlation coefficients between MBS month-on-month diffusion indices and PMIs

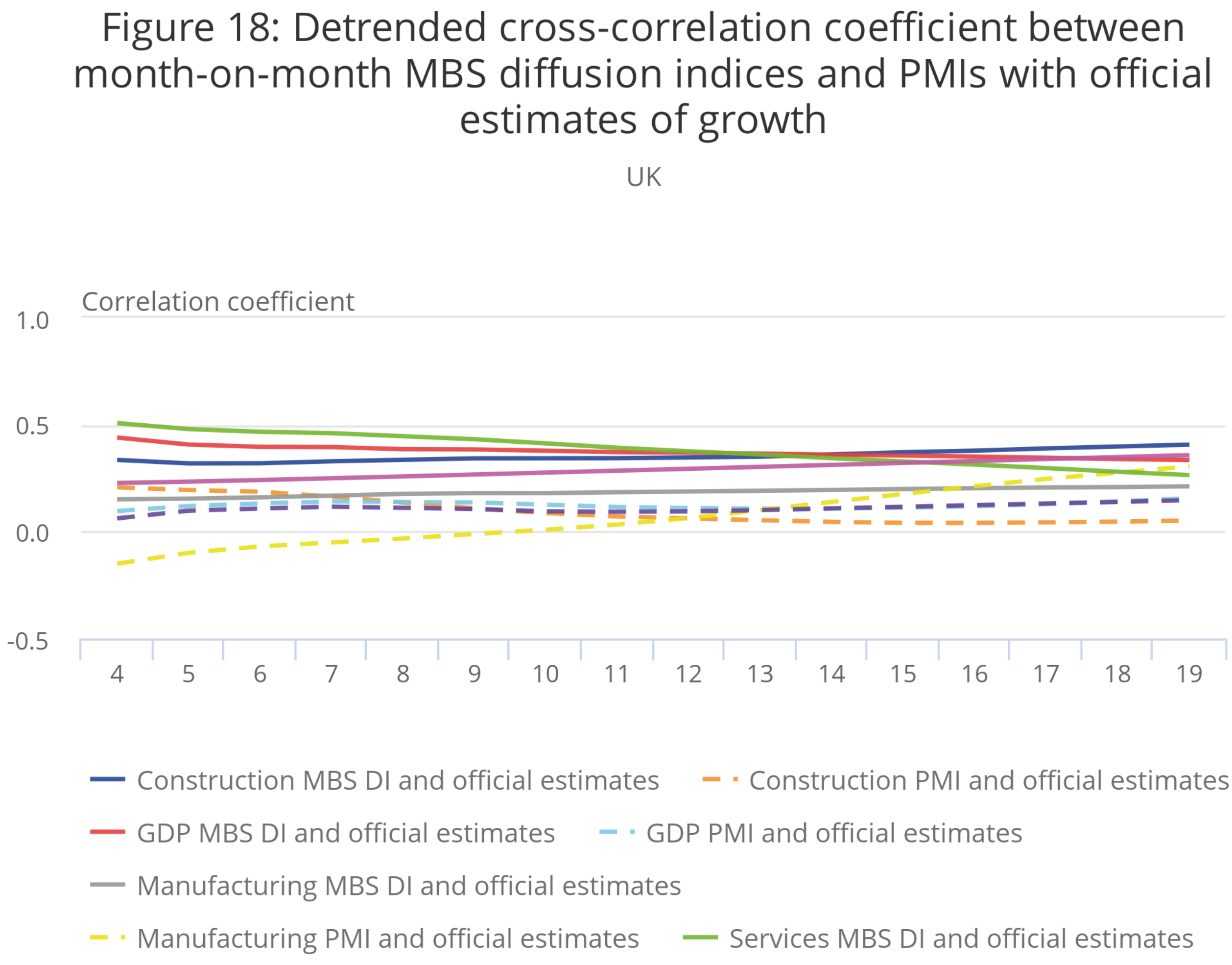
UK



Source: Office for National Statistics

Figure 18: Detrended cross-correlation coefficient between month-on-month MBS diffusion indices and PMIs with official estimates of growth

UK

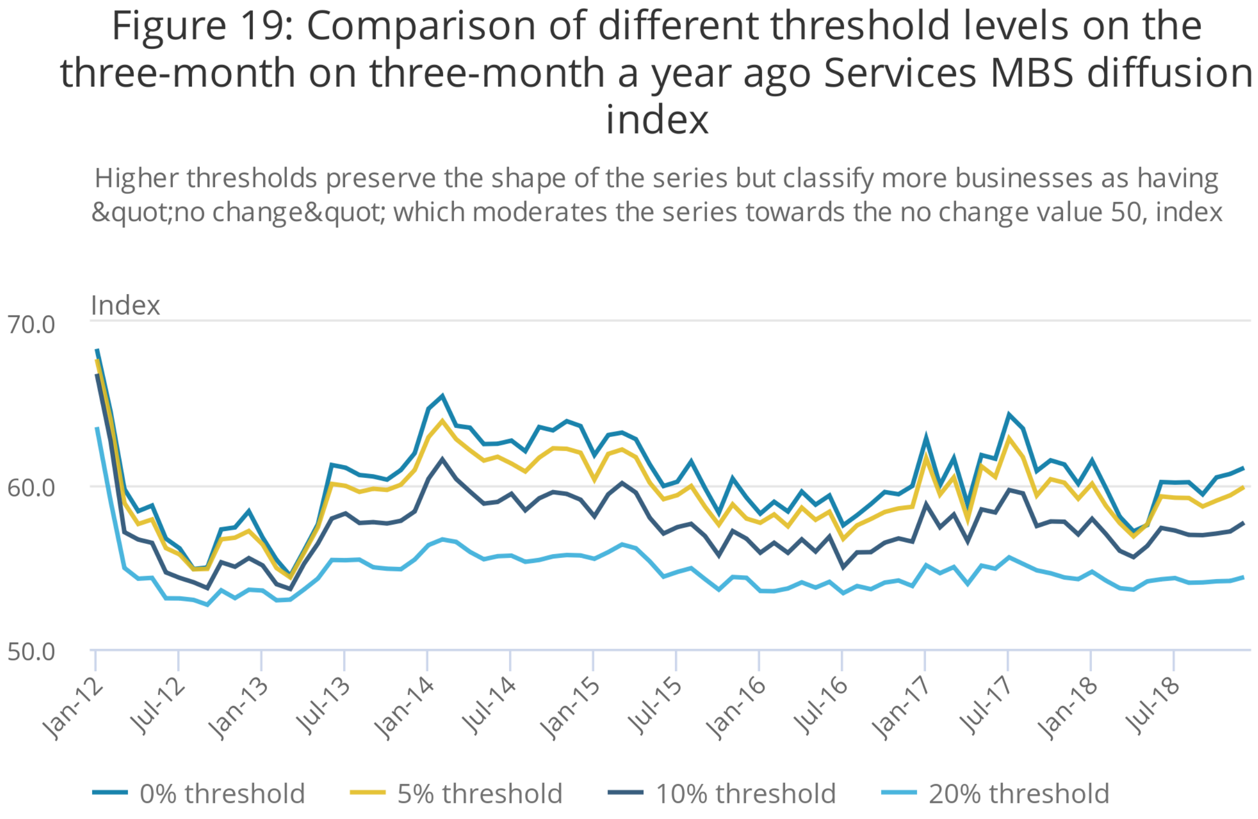


Source: Office for National Statistics

Threshold comparison

Figure 19: Comparison of different threshold levels on the three-month on three-month a year ago Services MBS diffusion index

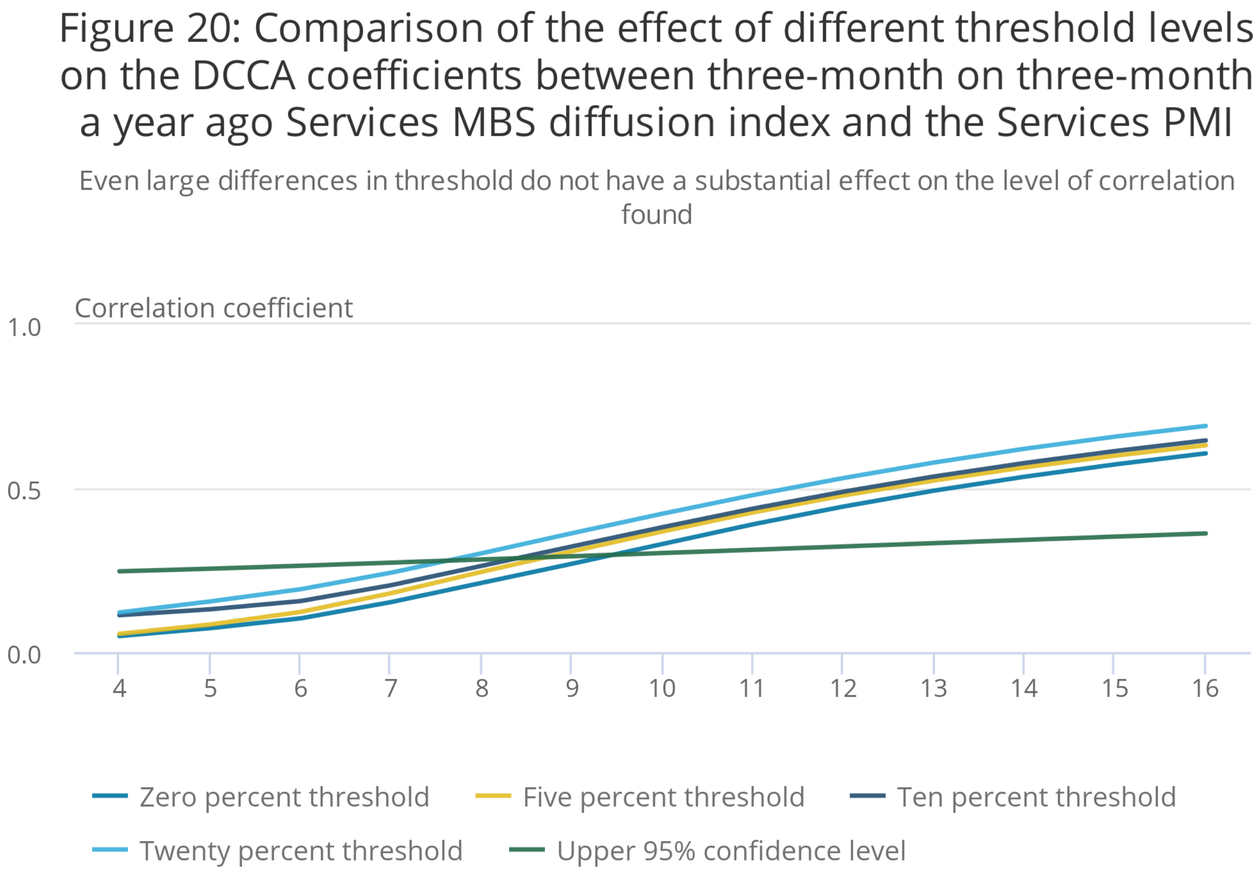
Higher thresholds preserve the shape of the series but classify more businesses as having "no change" which moderates the series towards the no change value 50, index



Source: Office for National Statistics

Figure 20: Comparison of the effect of different threshold levels on the DCCA coefficients between three-month on three-month a year ago Services MBS diffusion index and the Services PMI

Even large differences in threshold do not have a substantial effect on the level of correlation found



Source: Office for National Statistics

Sector coverage differences

ONS Services coverage: SICs 45000 to 97000

IHS Markit PMI Services coverage: SICs 49100 to 64999 ; 68100 to 82990 ; 90000 to 96090

ONS Manufacturing coverage: SICs 10100 to 33200 (excluding 19100-19209 and 24100-24340)

IHS Markit PMI Manufacturing coverage: SICs 10100 to 33200 ; 38300 to 38320 ; 58100 to 58190 ; 59200 to 59200

ONS Construction coverage: SICs 41000 to 43999

IHS Markit PMI Construction coverage: SICs 41000 to 43999

Compendium

The decoupling of economic growth from carbon emissions: UK evidence

How the UK's economy has developed over time and the efforts it has made to reduce its carbon dioxide (CO2) emissions.

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Release date:
21 October 2019

Next release:
To be announced

Table of contents

1 . Main points

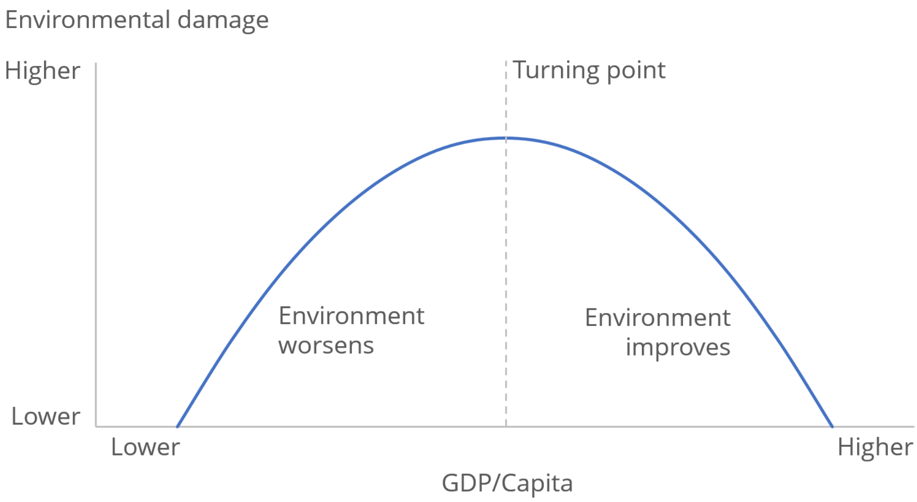
- While UK carbon dioxide (CO2) emissions peaked in 1972, once we consider imported emissions – such as when the UK imports products that are manufactured abroad – UK emissions peaked in 2007.
- The biggest source of these “imported” emissions is China, followed by the EU.
- Emissions produced directly by the UK declined as the result of a combination of environmental policies and a shift of the UK economy from more carbon-intensive manufacturing to less carbon-intensive service-based industries.
- When looking at the UK’s directly produced emissions, which continue to fall, the energy generation (negative 67%), manufacturing (negative 43%), water supply (negative 38%), and transport (negative 33%) sectors saw the biggest falls in emissions between 1990 and 2017.
- The change from coal to renewable energy has resulted in UK CO2 emissions continuing to fall.

2 . Introduction

The relationship between economic growth and the environment has become increasingly scrutinised in the last 100 years. The unprecedented growth of the world economy has resulted in an increasing concern that its development is a contributing factor to the greenhouse effect[1]. This topic has drawn upon various theoretical models, one of which is presented by the Environmental Kuznets Curve (EKC). The EKC was first recognised in 1992 as the relationship between concentrations of sulphur dioxide and per head gross domestic product (GDP) in 47 cities distributed over 31 countries (Yandle and others, 2004).

Figure 1: Initial increases in GDP per head result in increased greenhouse gas emissions but, as an economy transitions from industrial production to service-based industries the environmental damage gradually falls

Environmental Kuznet Curve



Source: Environmental Kuznets Curve

The EKC depicted in Figure 1 highlights the scale effect, which is the initial transition of the economy from agricultural production in rural areas to industrial production in urban areas. As industrial production intensifies, more energy is used, resulting in increased greenhouse gas (GHG) emissions through combustion. However, as the economy develops, there will be a structural change from manufacturing and industrial production to service-based industries. Higher economic development leads to better technology, environmental awareness and enforcement of environmental regulations resulting in the gradual decline of environmental degradation.

To inform the debate surrounding the UK's decoupling[2], we use data from the Office for National Statistics, the Bank of England, the Department for Business, Energy and Industrial Strategy (BEIS), the World Resources Institute (WRI) and Eora to explore the evolution of the EKC concept and its driving factors. Specifically, we focus on carbon dioxide (CO_2) effects, as these account for around 84% of all UK GHG emissions from human activities (please refer to Appendix A, for a breakdown of all UK GHG emissions).

The UK has shown evidence of absolute decoupling between 1985 and 2016, as gross domestic product (GDP) per head grew by 70.7%, while CO_2 emissions fell by 34.2%. This decoupling relationship is largely a result of the economic structural change, technological advancement and enforcement of environmental regulations such as the Climate Change Act in 2008. Under this Act, the UK is legally required to achieve the 2050 commitment to reduce GHG emissions by at least 80% compared with 1990 levels.

In May 2019, these targets were reassessed by the Committee on Climate Change (CCC). Their Net Zero Technical Report advises the UK to reduce GHG emissions by 100% from 1990 levels by 2050. The CCC also revised Scotland's targets to meet net-zero by 2045, and for Wales to reduce GHG emissions by 95% by 2050. These recommendations will deliver the commitment the UK made in the 2015 Paris agreement.

The evident economic structural change saw the services sector contribute to around 80% of total GDP in 2017, in comparison with 51% in 1948. As the UK's economy also witnessed technological development, the substitution of fossil fuels with renewable energy quickened substantially. For example, between 1990 and 2017, energy from renewable sources increased by 1,267%, while fossil fuel energy consumption declined by 22%, further diminishing its effect on pollution levels.

However, one of the criticisms of the EKC theory is that service-focused countries tend to create indirect emission by outsourcing the manufacturing of consumer items to countries with lower labour costs such as China. An increasing proportion of the UK's economy is devoted to the higher-value services sector, which consumes less energy. This raises emissions through international trade flows, exaggerating any apparent decline in territorial-based emissions. A global approach is needed to analyse the relationship between GDP and emissions. This article will contribute to the existing literature on the EKC theory by analysing the evolution of the EKC concept and the possible causes of an EKC-pattern in the UK.

Notes for: Introduction

1. Greenhouse effect – heat being trapped in the atmosphere resulting in temperature warming.
2. Decoupling occurs when the growth rate of an environmental pressure (for example, CO_2 emissions) is less than that of its economic driving force (for example, GDP per head) over a given period. Decoupling can be either absolute or relative. Absolute decoupling is said to occur when CO_2 emissions is stable or decreasing while the GDP per head growth is growing. While, relative decoupling is when the growth rate of the CO_2 emissions is positive, but less than the growth rate of the GDP per head (Ruffing, 2007).

3 . Background information

The relationship between gross domestic product (GDP) and the environment has become more important, because the rapid economic growth of developing countries has contributed to environmental degradation. The Environmental Kuznets Curve (EKC) theory suggests that economic growth will eventually reduce the environmental degradation created in the early period of development. Therefore, an economy should focus on economic growth in the short-term and any environmental effects will be counteracted in the long-term.

The observed evidence of the EKC theory is mixed, although most studies find evidence of an inverted-U shape relationship between real GDP per head and measures of environmental degradation such as sulphur dioxide and /or carbon dioxide emissions. De Bruyn and others (1998) argue that even though economic growth leads to an increase in emissions in the early stages of economic development, emissions may fall over time if there are technological and structural changes to the economy. More recent literature by Giovanis (2013), Mohapatra and others (2016), Mikayilov and others (2018), and Luzzati and others (2018) found that relative decoupling was more evident in developed countries. For example, Mikayilov and others (2018) used a panel data of European countries and found countries that showed evidence of decoupling followed stricter carbon mitigation policies. Therefore, it is necessary for the government to implement environmental policies such as carbon taxation, carbon pricing, cap and trade, and so on to ensure economies grow sustainably.

Everett and others (2010) and Luzzati and others (2018) agree with the conclusions of these studies to an extent. The results of Luzzati and others (2018) only showed weak evidence of EKC for the period 1971 to 2001 and found that this evidence does not hold up for the rest of their time frame because of the new wave of globalisation. The globalised nature of the world economy implies that this relationship needs to be analysed at an international level, rather than by individual countries because environmental damage cannot simply be reduced by moving production processes from advanced to developing countries (Everett and others, 2010).

4 . The relationship between environment and the economy

The UK Industrial Revolution of the 18th and 19th centuries resulted in the transition of the UK economy from a reliance on agriculture to manufacturing, starting a period of unprecedented economic growth. The carbon-intensive nature of the manufacturing sector meant that growth in the economy was accompanied by previously unseen levels of emissions.

Figure 2: Reduction in coal consumption and carbon dioxide emissions follow introduction of environmental regulations

GDP per head, territorial CO2 Emissions and coal consumption

Data download

Note:

1. Annual UK territorial CO2 emissions and coal consumption values were obtained from Carbon Brief, 2017; which used data sources via Department for Business, Energy & Industrial Strategy, 2019 and World Resources Institute, 2017. Real GDP per head values are sourced via Bank of England, 2019.

As observed in Figure 2, between 1850 and 1985, the UK's gross domestic product (GDP) per head and carbon dioxide (CO2) emissions exhibited a strong coupling, increasing by 516% and 354% respectively. The only exceptions were 1921, 1926 and 1984 where the miners' strikes led to a fall in coal production and caused a sharp dip in CO2 levels as observed previously (Church and others, 1990).

Most of this emission originated from the combustion of fossil fuels used to heat homes, such as coal , combined with emissions produced by factories during the Industrial Revolution. UK coal consumption increased from around 29 million tonnes a year in 1850 to 206 million tonnes in 1950.

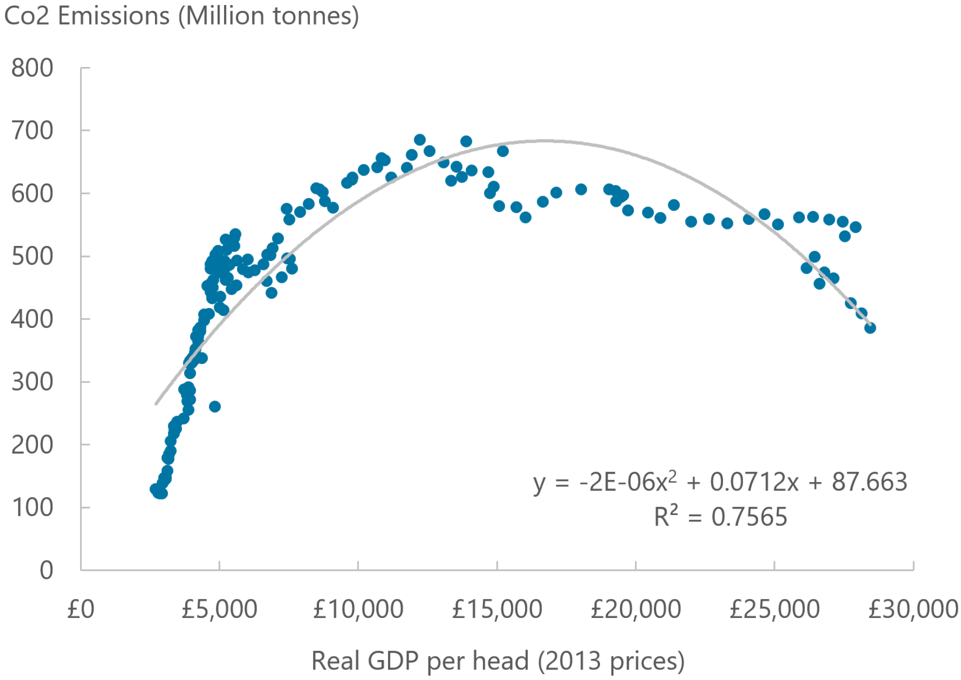
In 1952, smoke generated from the excess burning of coal combined with fog eventually led to a thick layer of smog in major cities such as London, Glasgow, Leeds and Manchester. The smog blocked out the sun, blackened buildings, increased the seriousness of fog, and damaged people's health (Brimblecombe, 2006).

According to the Environmental Kuznets Curve (EKC) theory, the decoupling of economic growth from environmental degradation eventually occurs after a certain GDP per head level. This is because higher economic development leads to environmental awareness, enforcement of environmental regulations and better technology, resulting in the gradual decline of environmental degradation. In a UK context, environmental awareness and a political appetite for enforcement of environmental regulations may have been a precedent for the eventual reduction in CO_2 emissions.

The London smog prompted creation of the Clean Air Acts of 1956 and 1968, which prohibited discharges of dark smoke and declared that the inhabitants of urban regions and administrators of processing plants must switch over to smokeless fuels. By shifting domestic sources of heat towards cleaner coal, electricity and gas, it reduced the amount of smoke pollution and carbon dioxide from household fires and contributed to the eventual decline of coal (Brimblecombe, 2006). The level of coal consumption is shown in Figure 2 to decline after 1956.

Figure 3: The approximate turning point for decoupling of GDP per head and carbon dioxide emissions seems to have been around 1985

Correlation between real GDP per head and CO_2 Emissions (Tonnes), 1850 to 2016



Source: Bank of England, 2019, World Resources Institute, 2017 and Business Energy Industrial Strategy, 2019

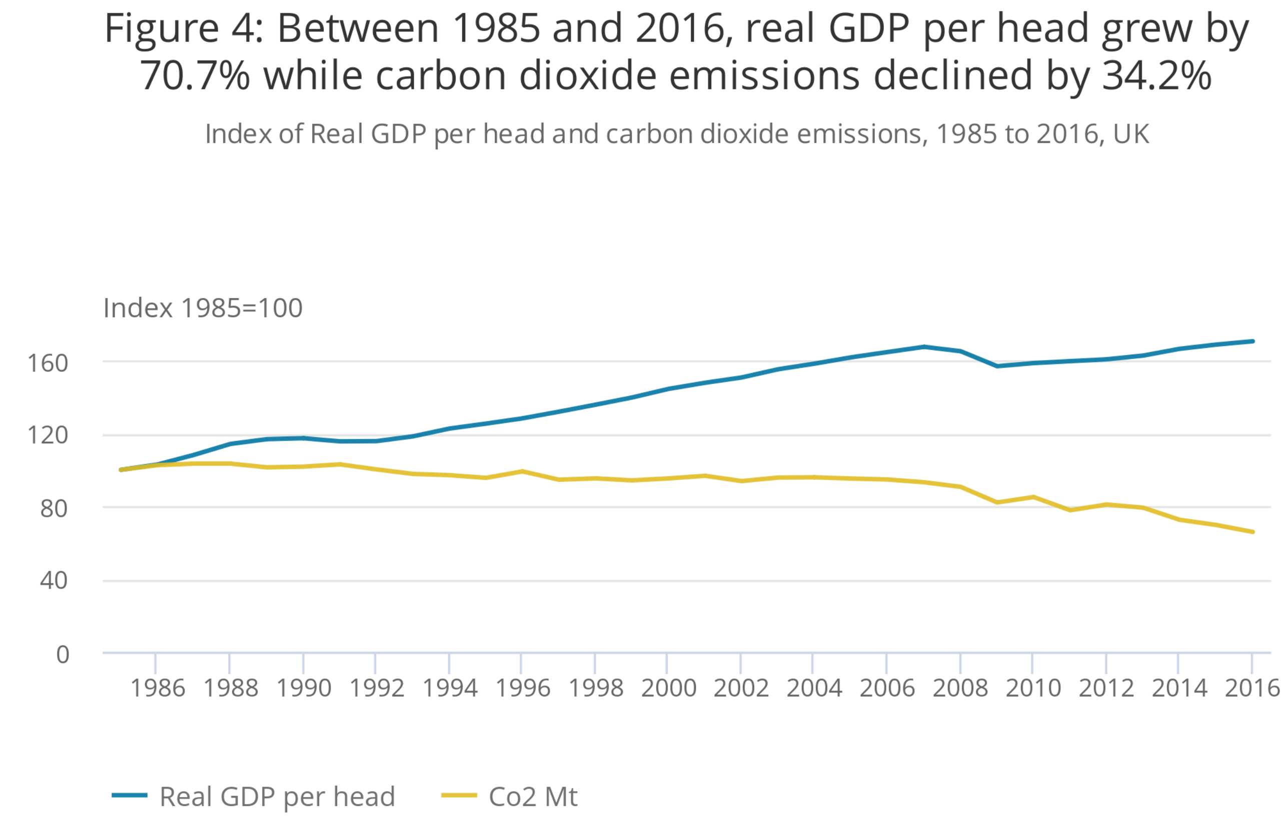
Notes:

1. Annual UK CO_2 emissions were obtained from Carbon Brief, 2017; which used data sources via Business, Energy and Industrial Strategy , 2019 and World Resource Institute, 2017. Real GDP per head values are sourced via Bank of England, 2019.

For the UK, the approximate turning point at which the decoupling of GDP per head and carbon dioxide emissions seemed to have happened was in 1985, with a GDP per head of £16,667 and corresponding CO_2 emissions of around 586 million tonnes, as shown in Figure 3. For a more in-depth analysis of the turning point calculation, please refer to Appendix C.

Figure 4: Between 1985 and 2016, real GDP per head grew by 70.7% while carbon dioxide emissions declined by 34.2%

Index of Real GDP per head and carbon dioxide emissions, 1985 to 2016, UK



Source: Bank of England, 2019, World Resources Institute, 2017 and Business Energy Industrial Strategy, 2019

Notes:

1. Annual UK CO2 emissions were obtained from Carbon Brief, 2017; which used data sources via Business, Energy and Industrial Strategy , 2019 and World Resource Institute, 2017. Real GDP per head values are sourced via Bank of England, 2019.

Figure 4 shows absolute decoupling of real GDP per head and carbon dioxide emissions, with 1985 as the base year to reflect changes following the decoupling. Real GDP per head grew by 70.7% between 1985 and 2016 while carbon dioxide emissions declined by 34.2% during the same period.

The Climate Change Act of 2008 (PDF, 440KB) was a further effort by the government to reduce the UK's impact on the environment. The Act formalised the UK's approach to tackling climate change and required preparation for climate change risks, as well as the reduction of the net UK carbon account of at least 80% by 2050, compared with 1990 levels.

The rate of decline in carbon dioxide (CO2) emissions quickened from 2008 as shown in Figure 4. The global economic slowdown during this period is likely to have contributed to the initial decline in emissions because of a reduction in global demand, therefore the exact impact of the Act on CO2 emissions is uncertain. However, the continued decline in emissions following the economic recovery is evidence of environmental improvement. In 2016, CO2 emissions were 35% below 1990 levels while GDP per head grew by 45% over the same period.

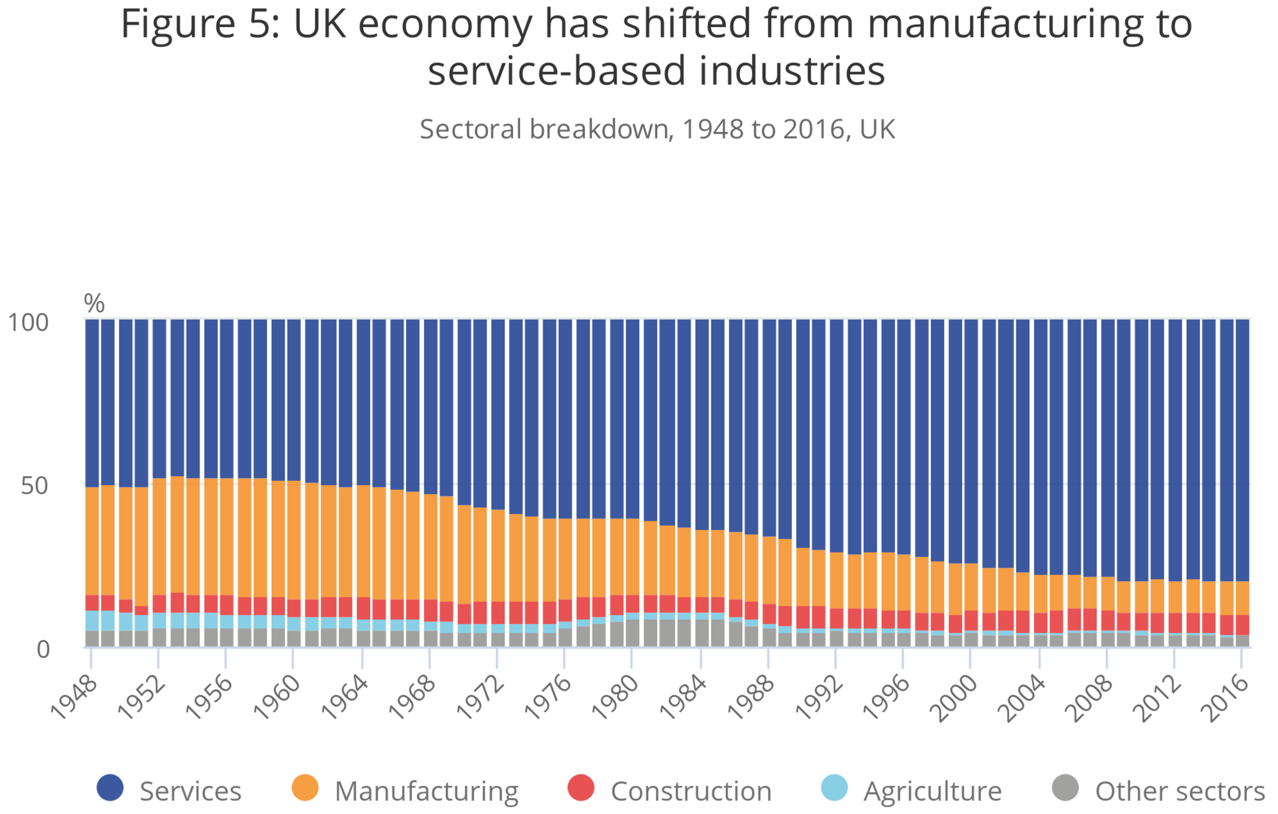
The Climate Change Act was amended in 2019 following the recommendations of the Committee on Climate Change to introduce the target of at least a 100% reduction of the net UK carbon account by 2050 compared with 1990 levels. The policies described previously highlight the importance of environmental policy for reducing the UK's environmental impact while maintaining economic growth. However, there could be several other reasons for decoupling of GDP per head from CO2 emissions, such as the structural change in the UK economy and technological advancement.

5 . UK's structural change

The structural transformation of the economy is relevant to the Environmental Kuznets Curve (EKC) concept. The theory suggests that economic development results in a structural change that transfers the economic production system from low-polluting agricultural industries to pollution-intensive manufacturing sectors and shifts again to less carbon-intensive service sectors.

Figure 5: UK economy has shifted from manufacturing to service-based industries

Sectoral breakdown, 1948 to 2016, UK



Source: Bank of England, 2019

Consistent with the EKC theory, Figure 5 shows that the UK economy is now devoted towards the services sector. In particular the knowledge-intensive services such as finance, professional services, and information and communication technology (Department for Business, Innovation and Skills, 2012).

For example, between 1986 and 2017, the services sector contributed an average of 74% towards total gross domestic product (GDP). In comparison, the manufacturing sector contributed 14% to UK GDP in the same period. An important factor behind this structural change is the rapid pace of globalisation and technological advancement, which has led to rising productivity of manufactured goods and competition from low-wage economies (Department for Business, Innovation and Skills, 2012).

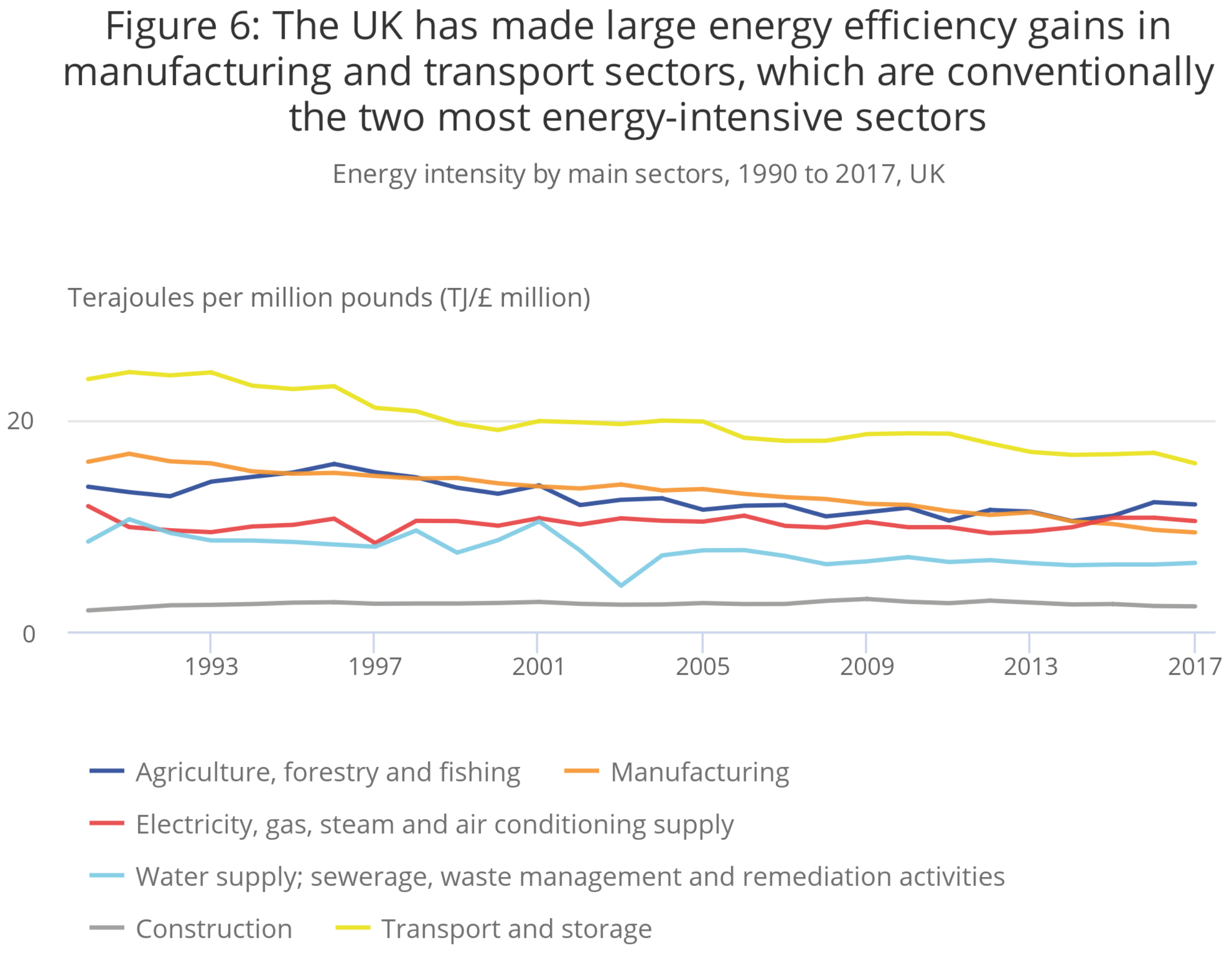
Furthermore, a growing global middle class, particularly in emerging economies, has expanded the UK's export market across services sectors, such as creative and professional business services, further increasing the share of the UK's services industry. The structural change of the UK economy from manufacturing to a service-based economy has significantly contributed to the decline in carbon emissions. This is because the services industries have lower carbon intensity compared with manufacturing.

6 . Technical progress and improvements in energy efficiency

According to the Environmental Kuznets Curve (EKC), higher economic development leads to technological advancement, enabling production processes to become cleaner and more resource-efficient. The development of advanced technologies that enable the efficient use of natural resources is vital in reducing environmental degradation caused by the production of goods and services.

Figure 6: The UK has made large energy efficiency gains in manufacturing and transport sectors, which are conventionally the two most energy-intensive sectors

Energy intensity by main sectors, 1990 to 2017, UK



Source: Office for National Statistics, 2019a

Energy intensity provides a broad indication of how efficiently energy is being used over time. The higher the energy efficiency, the lower the energy intensity by sector.

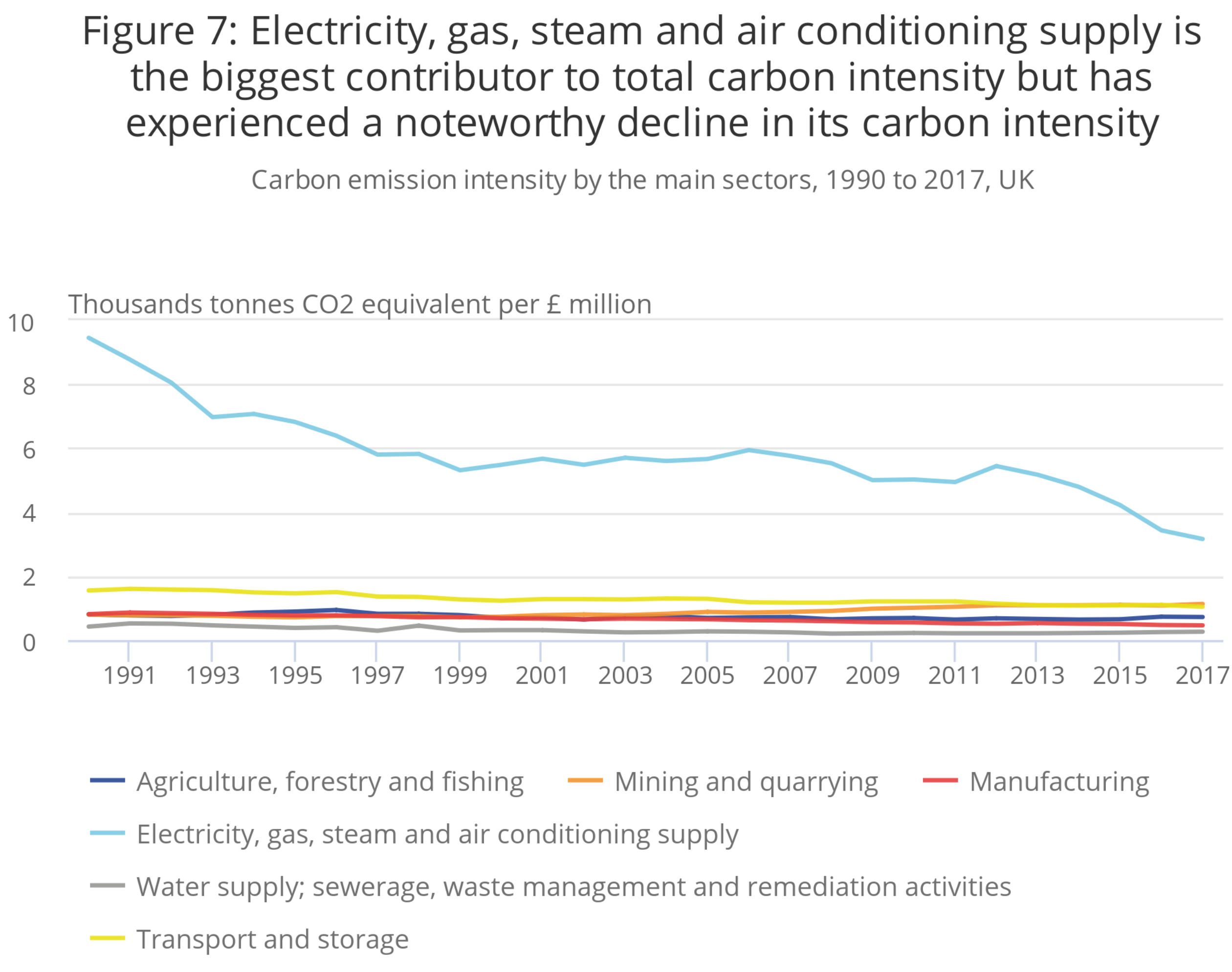
The UK has already made large energy efficiency gains specifically in the manufacturing and transport sectors, which are conventionally the two most energy-intensive sectors (Office for National Statistics, 2018). The largest fall in energy intensity occurred in the manufacturing sector, by 42% between 1990 and 2017, due mainly to the shift of the UK economy from a manufacturing to a service-based economy.

The decreasing importance of the manufacturing sector has resulted in the transportation sector now demanding most of the energy used in the economy, a share of 80% (Department for Environment, Food and Rural Affairs, 2018). Furthermore, energy intensity in the transport and storage sector declined by 33% over the observed period.

A major contributing factor to this decline is improvement in the efficiency of vehicles. For example, the use of composite materials and carbon fibre[1] technology in building vehicles achieves weight savings of 30% compared with traditional cold roll forming grades[2], therefore, improving its fuel economy (Furfari, 2016).

Figure 7: Electricity, gas, steam and air conditioning supply is the biggest contributor to total carbon intensity but has experienced a noteworthy decline in its carbon intensity

Carbon emission intensity by the main sectors, 1990 to 2017, UK



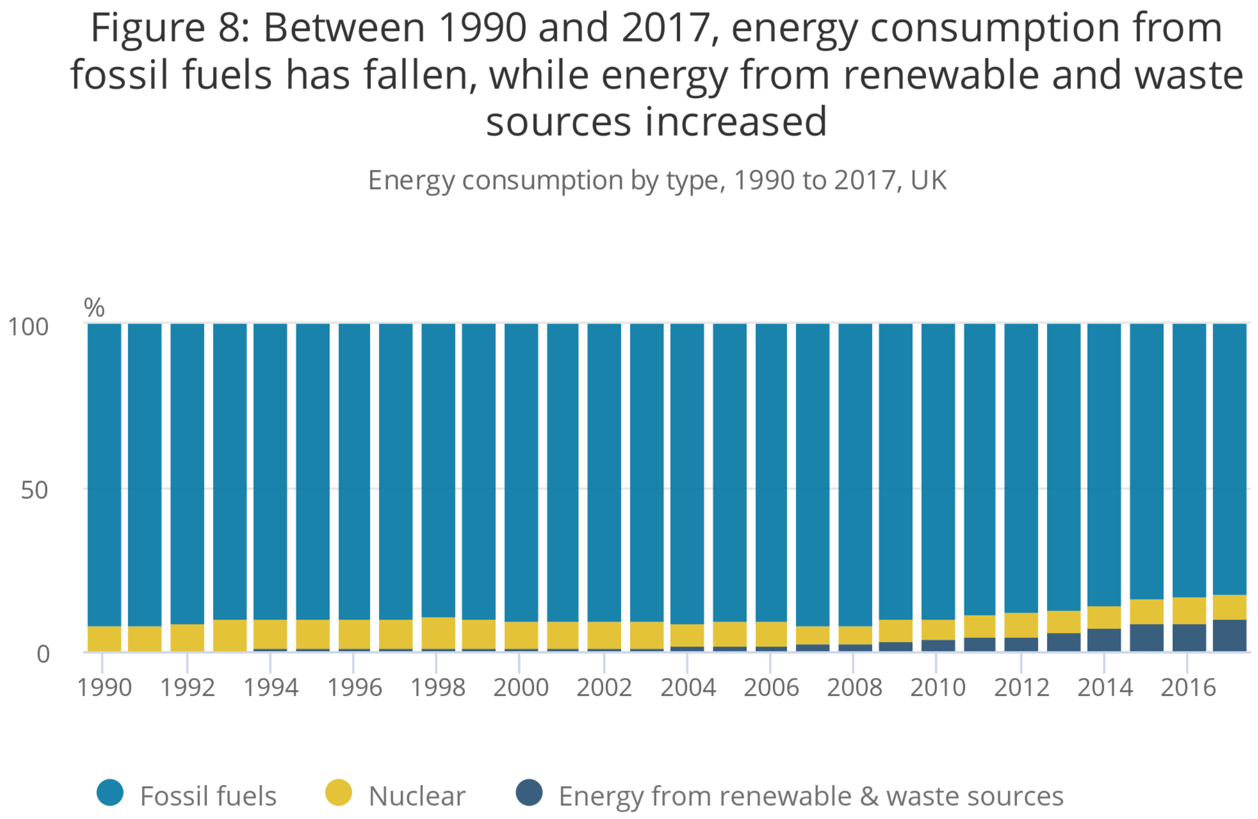
Source: Office for National Statistics, 2019b

Carbon dioxide (CO_2) emissions are directly related to the use of energy as CO_2 emissions are by-products of energy consumption. Therefore, because of the decrease in energy demand, the intensity of greenhouse gas emissions also diminishes. In recent years, CO_2 emissions per unit of economic activity, as measured by the carbon intensity[3], has been declining.

Figure 7 shows that the electricity, gas, steam and air conditioning supply industry is the biggest contributor to total carbon intensity, representing an average share of 15% between 1997 and 2017. This is because approximately 68% of electricity production comes from burning fossil fuels, mostly coal and natural gas. However, this sector has witnessed the most noteworthy decline in its carbon intensity, by 67% over the same period.

Figure 8: Between 1990 and 2017, energy consumption from fossil fuels has fallen, while energy from renewable and waste sources increased

Energy consumption by type, 1990 to 2017, UK



Source: Office for National Statistics, 2019c

These were driven primarily by a switch from the use of coal and heavy-polluting fuels to other, more efficient fuels such as natural gas and, more recently, renewable sources[4] (Office for National Statistics, 2019d). This is shown in Figure 8, as energy consumption from fossil fuels fell 22% between 1990 and 2017 to 161.6 million tonnes, while energy from renewable and waste sources increased by 1,267% over the same period, reaching 20.5 million tonnes.

The reduction in the use of fossil fuels as the primary source of energy for electricity generation has contributed to 130 million tonnes fewer CO_2 emissions produced between 1990 and 2017 (Business, Energy and Industrial Strategy, 2019).

Despite the transition to more renewable energy consumption for electricity generation and other uses, energy consumption from renewable sources only represented 10% of total energy consumption in 2017. However, this shows an improvement when compared with its 1% contribution in 1990.

Notes for: Technical progress and improvements in energy efficiency

1. Carbon fibre is a material consisting of fragile filaments of carbon atoms. When bound with plastic polymer resin by heat, pressure or in a vacuum, a composite material is formed that is both strong and lightweight (Rezaei and others, 2008).

2. Cold roll forming process is an alternative method to shape the advanced high strength steel using a series of rolls under the condition of room temperature (Sheu and others, 2017).

3. Air emissions form part of the United Nations (UN) 17 Sustainable Development Goals (SDGs), which were introduced in 2015. Their primary purpose is to end poverty, protect the planet and ensure that everyone enjoys peace and prosperity by 2030. The UK has contributed towards Indicator 9.4.1 by reducing its carbon intensity. The primary aim of this goal is for industries to reduce their carbon dioxide (CO_2) intensity through technological advancement that enables industrial processes to become cleaner and resource-efficient. More information about SDGs can be found on the ONS and UN websites.

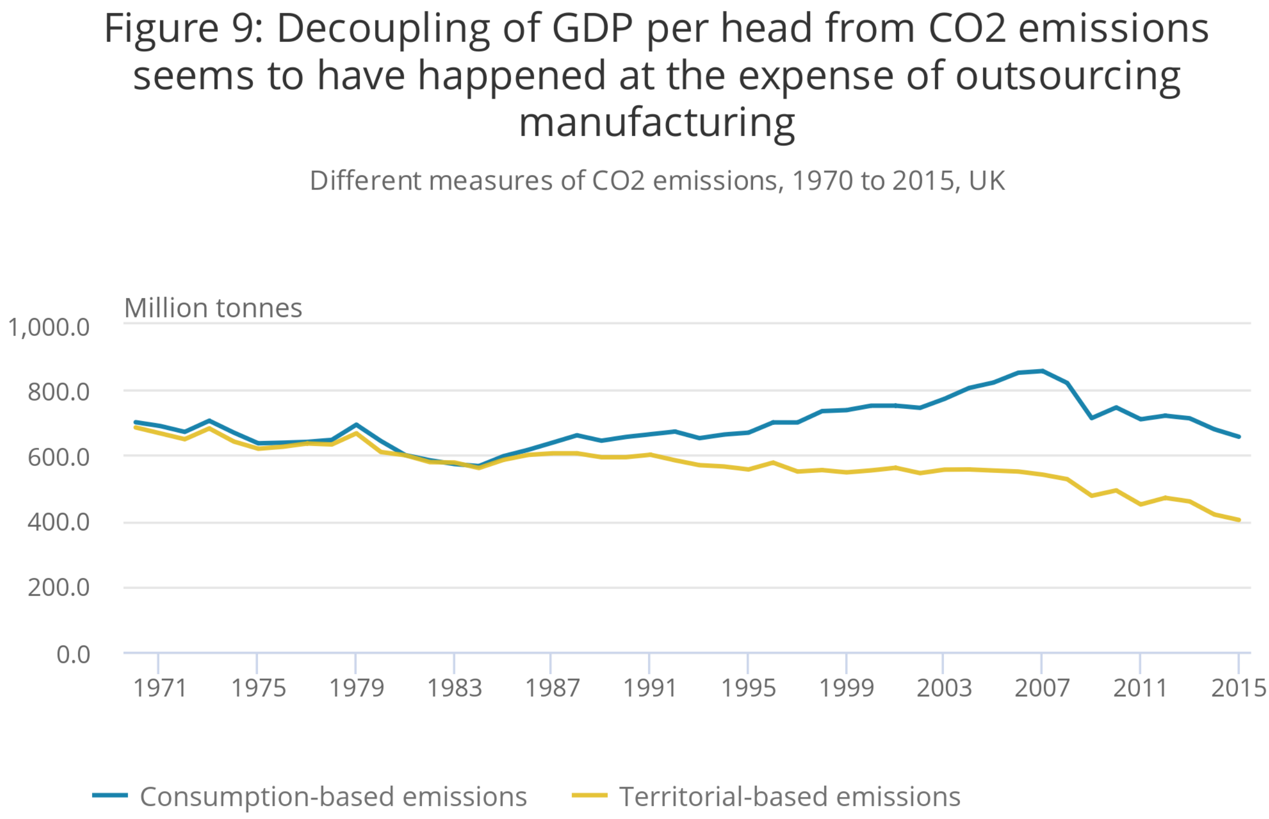
4. The UK's largest source of renewable energy consumed is derived from biomass – that is, organic material from plants or animals and not solar or wind energy. More information about the impact of UK's biomass energy consumption can be found on the ONS website.

7 . International trade of carbon emissions

The sudden expansion and globalisation of world economies has resulted in service-focused countries and regions creating indirect emissions through outsourcing of manufacturing products to countries with lower labour costs. Hence, carbon dioxide (CO_2) emissions embodied in international trade have become an essential factor in the measurement of global carbon emission responsibility. Different approaches can be taken to measure and account for carbon emissions such as Territorial[1], Residency and Consumption basis[2].

Figure 9: Decoupling of GDP per head from CO2 emissions seems to have happened at the expense of outsourcing manufacturing

Different measures of CO2 emissions, 1970 to 2015, UK



Source: Eora, 2018, World Resource Institute, 2017 and Department for Business, Energy and Industrial Strategy, 2019b

Notes:

1. This graph has been compiled using data for consumption-based emissions from Eora, 2018, and territorial-based emissions from WRI, 2017 and BEIS, 2019

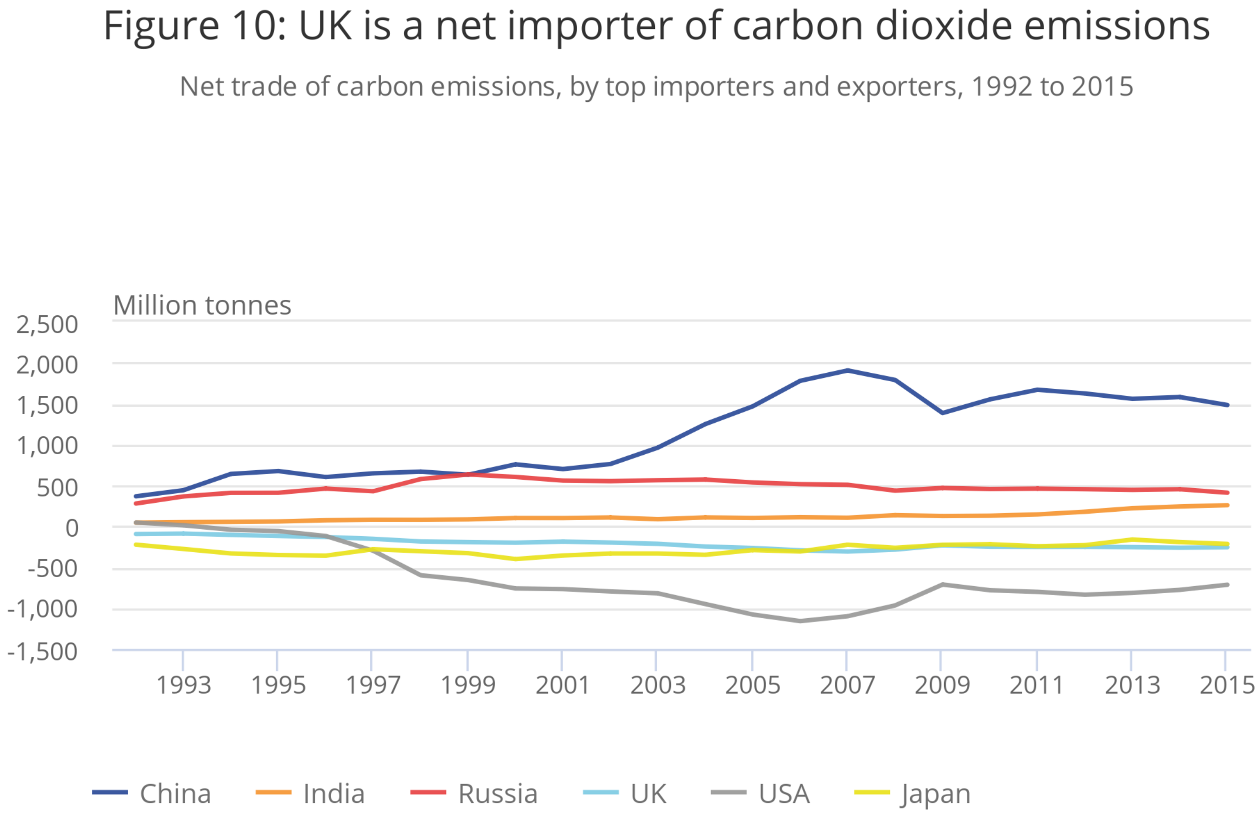
Figure 9 shows that, on average between 1970 and 1986, consumption-based emissions were only 0.2% higher than territorial-based emissions. This is attributed to the UK importing fewer emissions embodied in manufactured goods, because during that period, the UK had a larger manufacturing sector that met domestic demand for goods.

The UK economy gradually shifted from a carbon-intensive manufacturing-based economy to a less carbon-intensive services economy after-1986. The gap between the consumption-based and territorial-based emissions started to widen. By 2007, the consumption-based CO2 emissions reached their peak and were 37% higher than the territorial CO2 emissions. This implies that the absolute decoupling of gross domestic product (GDP) from territorial CO2 emissions in 1986 was not solely because of policy impacts, but also because of the outsourcing of the production of manufactured goods to developing countries.

Since 2008, both the territorial and consumption-based emissions have declined. This reduction in emissions coincided with the global economic downturn. However, both types of emissions have continued to decline since the economic recovery.

Figure 10: UK is a net importer of carbon dioxide emissions

Net trade of carbon emissions, by top importers and exporters, 1992 to 2015



Source: Eora, 2018

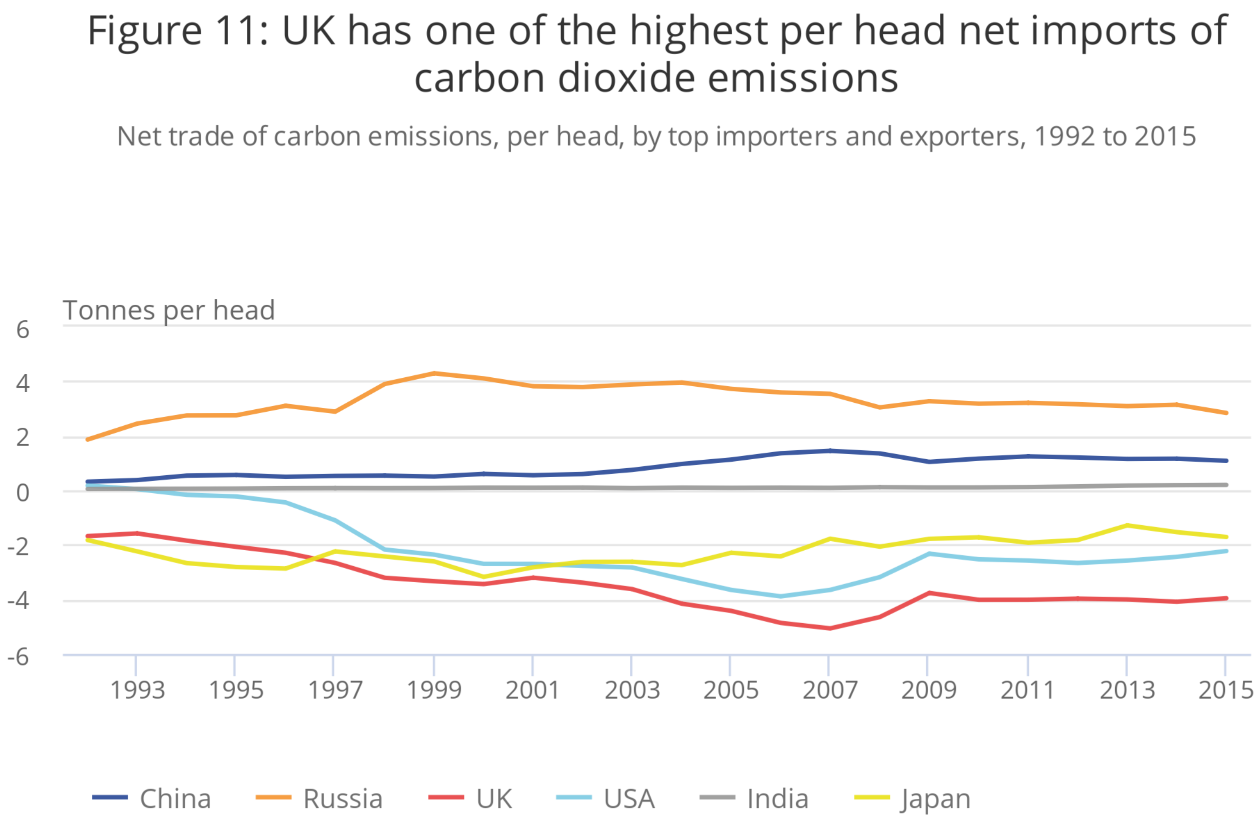
Figure 10 compares the largest net importers and exporters of CO_2 emissions. A country can be considered a net exporter of CO_2 emissions when its territorial-based emissions are higher than its consumption-based CO_2 emissions. The reverse is true for the UK, being a net importer of CO_2 emissions as seen in Figure 9.

The United States (US) is the largest net importer of CO_2 emissions. In 1992, the US had a net import of 43.5 million tonnes of CO_2 emissions, which increased to 717 million tonnes by 2015.

China is the biggest net exporter of CO_2 emissions. In 1992, China had a net export of 364 million tonnes of CO_2. This increased to 1,480 million tonnes by 2015. This demonstrates that while the US and many other developed countries have reduced their domestic emissions over recent decades, some of this decrease has been counteracted by rising imports from countries, such as China, which have a more carbon-intensive energy mix. This highlights the main criticism of the Environmental Kuznets Curve theory.

Figure 11: UK has one of the highest per head net imports of carbon dioxide emissions

Net trade of carbon emissions, per head, by top importers and exporters, 1992 to 2015



Source: Eora, 2018

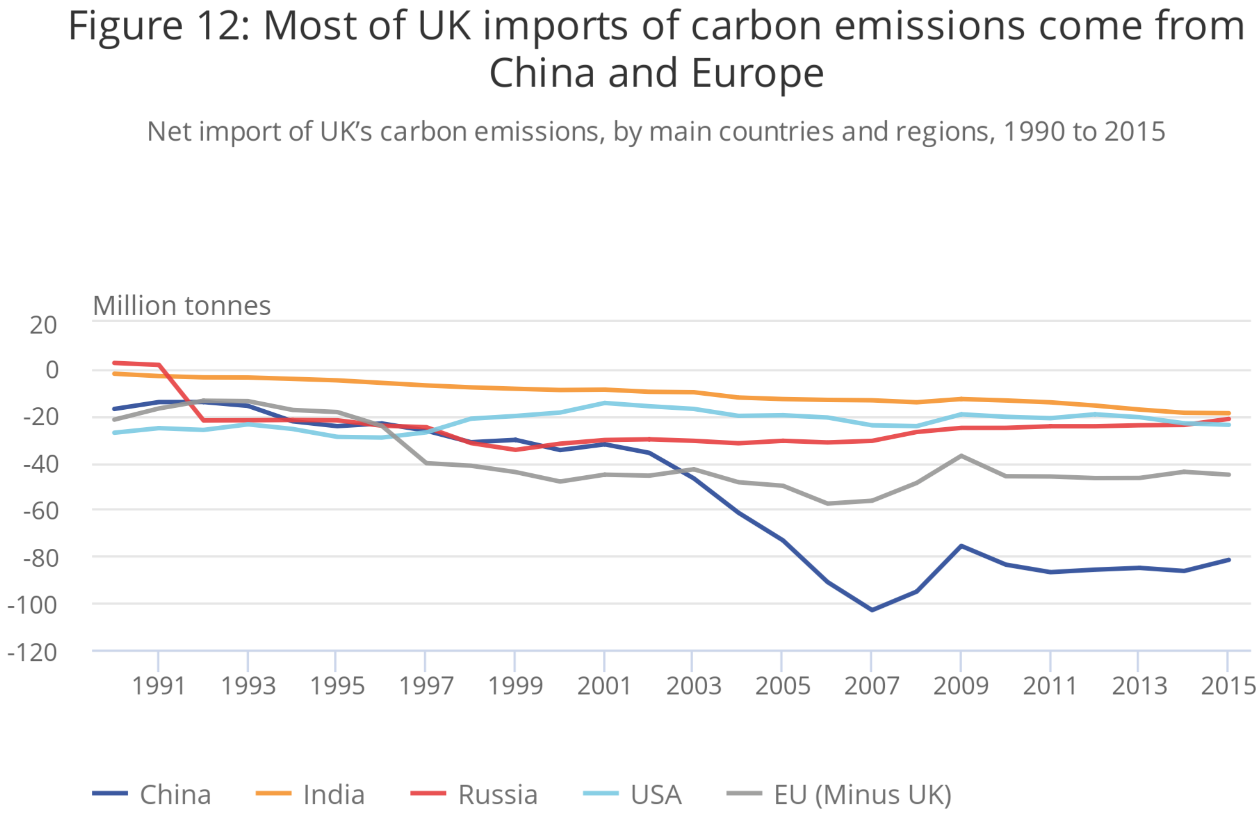
Comparisons between countries can be difficult because of their respective population and size. These factors have large impacts on resulting carbon transfers. Thus, Figure 11 shows CO_2 net exports considering differences in population.

Despite the US having the largest net CO_2 emission imports, US net import of CO_2 emissions per head are lower than that of the UK. The UK increased its net imports of CO_2 emissions per head from 1.7 tonnes in 1992 to 5.1 tonnes per head in 2007. However, the UK comprises around 3.7% of the world's GDP (World Bank, 2019) and 1.9% of CO_2 emissions based on consumption in 2011 (Organisation for Economic Co-operation and Development, 2015). As a result, the UK represents a relatively small proportion of CO_2 emissions embodied in global trade.

Taking into consideration population differences, the UK is the largest net importer of carbon dioxide amongst these selected countries and regions. China is replaced by Russia as the most prominent net exporter of CO_2 emissions. In 2015, Russia had a net-export of 2.8 tonnes of CO_2 per head, while China's net-export was 1.1 tonnes per head. This is substantially different to the trend seen in Figure 10. Taking population differences in consideration significantly changes the global outlook of carbon emissions embodied in international trade.

Figure 12: Most of UK imports of carbon emissions come from China and Europe

Net import of UK's carbon emissions, by main countries and regions, 1990 to 2015



Source: Eora, 2018

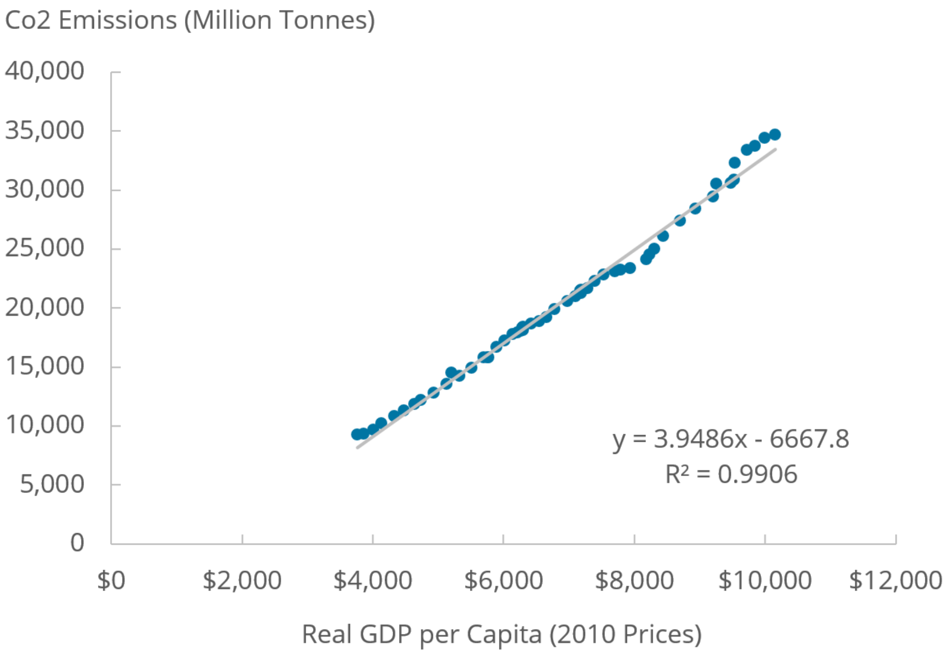
Figure 12 breaks down international trade of carbon emissions by showing the main countries and regions the UK imports carbon emissions from. The chart shows that the UK has the highest net import of carbon emissions from China, which reached a peak of 53 million tonnes of CO2 emissions in 2007. A briefing by the House of Commons states that the UK's largest import from China was telecoms equipment in 2017. A study published in the Nature Climate Change Journal found that products made in China are associated with higher CO2 emissions than if the same products were made elsewhere. This is because China uses less advanced manufacturing processes and relies primarily on coal for energy (Liu, Z. and others, 2016).

However, Figure 9 shows that consumption-based CO2 reductions have continued despite recovery from the economic downturn after-2008. The UK's carbon footprint fell by approximately 3.4% between 2014 and 2015. This is because of a fall in emissions associated with imported goods, particularly from China. In addition, there has been a fall in the final demand of CO2 emissions from imported energy, which could have helped drive down consumption-based emissions (Hardt, L. and others, 2018).

The UK's net import of CO2 emissions from Europe in 2007 was around 63 million tonnes, but this fell to 32 million tonnes in 2009. The sharp fall in imported carbon emissions from Europe from 2007 onwards highlighted in Figure 12 could be attributed to the Kyoto Protocol. Under the protocol, countries pledged to reduce their emissions from 2008 to 2012, thus the European Union also follows the same trend. Environmental awareness, political appetite and policy focus all suggest that in the last 10 years the UK has made a genuine effort to cut carbon emissions.

Figure 13: There is still a strong coupling between world carbon dioxide emissions and real GDP per head

Correlation between real GDP per head and CO2 emissions (tonnes) globally, 1960 to 2014



Source: World Bank, 2019 and World Resources Institute, 2017

While the UK economy is a good example of Environmental Kuznets Curve theory and has shown signs of absolute decoupling following 1985, Figure 13 demonstrates that this has not been the case when looking at the same comparison globally. There is still a strong coupling between carbon dioxide emissions and real GDP per head.

An important reason for this is the continued reliance on manufacturing in many countries, which is carbon-intensive. When the UK was heavily reliant on the manufacturing sector following the Industrial Revolution, a similar coupling between GDP per head and CO2 emissions occurred. At a global level, a structural change such as the one witnessed in the UK is unlikely because of the global demand for manufactured goods, therefore any potential global decoupling must be achieved through other factors such as technological change or environmental policies.

It is useful to look at environmental policies from a global perspective as pollution has no production boundary and its negative effect is felt worldwide. While policies such as those highlighted in previous sections are beneficial for reducing domestic emissions, the current absence of a global approach provides an incentive to outsource the production of emissions to countries with less stringent regulations, resulting in the continued rise of global emissions despite domestic improvements.

Notes for: International trade of carbon emissions

1. Territorial approach only measures emissions that occur within the UK's borders. On a residency basis, the figures reflect emissions produced by UK residents and industries (UK and abroad) but exclude emissions within the UK, which can be attributed to overseas residents and businesses. Consumption measures emissions of UK residents on goods and services, wherever in the world these emissions arise in the production process and that are directly caused by UK households (Source: Defra).

2. Consumption-based accounting (CBA) of emissions is a relatively new and emerging field both in policy and academic research. Therefore, the current measurements are rarely regarded as "official statistics" because of the variability in the CBA results across multi-regional input-output table (MRIO) models. These variations relate to issues such as calibration, balancing, and harmonisation, the use of different time periods, different currencies, different country classifications, levels of disaggregation, inflation and raw data errors (Barrett and others, 2013). Nevertheless, the use of error propagation such as the Monte-Carlo simulation techniques can be applied to account for such uncertainties. For example, Moran and Wood (2014), Monte Carlo sensitivity analysis results show that the CBA results across MRIOs models differ by less than 10% for most major economies and this is considered acceptable.

8 . Conclusion

This article analyses how the UK's economy has developed over time and the efforts it has made to reduce its carbon dioxide (CO2) levels. The early stages of economic growth in the UK brought about by the Industrial Revolution led to increases in greenhouse gas emissions. However, following the 1952 London smog, many environmental acts have been adopted as part of a proactive approach to reduce CO2 emissions.

Our analysis shows that the UK has gone through structural changes to become a service-led economy. The structural shift away from manufacturing has significantly contributed to the decline in carbon emissions because of the services industries having a comparatively lower carbon intensity.

Technological progress in the UK has resulted in a decline in CO2 emissions by bringing improvements in energy intensity and carbon emission intensity. The UK economy saw a significant decrease of energy intensity in the manufacturing and transport sectors, which are the most predominant energy-intensive sectors. As the UK's economy also witnessed technological development, the substitution of fossil fuels for renewable energy has been increasing.

The drivers of the Environmental Kuznets Curve (EKC) pattern have resulted in an absolute decoupling of gross domestic product (GDP) from CO2 emissions. The UK is committed to further decline in CO2 emissions following the Climate Change Act and the 2050 target to achieve net zero emissions. The EKC theory experience in the UK shows that GDP growth can result in lower CO2 emissions, however, this needs to be combined with a political appetite to correct the market failure of over-production of CO2.

The impact of globalisation on CO2 emissions has resulted in service-based economies creating indirect emissions by outsourcing manufacturing products to countries with lower labour costs and less stringent pollution regulations. We find that the UK is a net-importer of CO2 emissions, with most of the imported CO2 emissions coming from China. Therefore, any apparent decline in territorial CO2 emissions is overestimated. However, in recent years the UK has made genuine efforts in cutting down both its territorial and consumption-based emissions despite continued growths in its GDP per head.

While the UK has shown evidence of absolute decoupling of GDP per head and CO2 emissions, the global coupling of GDP per head and CO2 emissions has persisted. Given there is no production boundary for air pollution, the reduction of air emissions while maintaining GDP growth, is a global responsibility.

9 . Authors

George Agbugba, Ginevra Okoye, Mamta Giva, and Joseph Marlow.

10 . References

Bank of England, 2019. A millennium of macroeconomic data

Barrett, J., Peters, G., Wiedmann, T., Scott, K., Lenzen, M., Roelich, K. and Le Quéré, C., 2013. Consumption-based GHG emission accounting: a UK case study. Climate Policy, volume 13, number 4, pages 451 to 470

Business, Energy and Industrial Strategy, 2019a., Historical coal data: coal production, availability and consumption

Business, Energy and Industrial Strategy, 2019b., Final UK greenhouse gas emissions national statistics: 1990-2017

Business, Innovation and Skills, 2012. Industrial Strategy: UK Sector Analysis. BIS Economics paper number 18

Bruyn, S.D., Van den Bergh, J.C.J.M. and Opschoor, J.B., 1998. Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. Ecological Economics, volume 25 number 2, pages 161 to 175

Carbon Brief, 2017., UK Emissions

Church, R., Outram, Q. and Smith, D.N., 1990. British coal mining strikes 1893–1940: Dimensions, distribution and persistence. British Journal of Industrial Relations, volume 28 number 3, pages 329 to 349

Department for Environment, Food and Rural Affairs, 2018., UK Energy Brief

Eora, 2018., Carbon Footprint of Nations

Everett, T., Ishwaran, M., Ansaloni, G.P. and Rubin, A., 2010. Economic growth and the environment. Defra Evidence and Analysis Series, paper 2

Furfari, S., 2016. Energy efficiency of engines and appliances for transport on land, water, and in air. Ambio, volume 45 number 1, pages 63 to 68

Giovanis, E., 2013. Environmental Kuznets curve: Evidence from the British household panel survey. Economic Modelling, 30, pages 602 to 611

Hardt, L., Owen, A., Brockway, P., Heun, M.K., Barrett, J., Taylor, P.G. and Foxon, T.J., 2018. Untangling the drivers of energy reduction in the UK productive sectors: Efficiency or offshoring? Applied energy, 223, pages 124 to 133

Liu, Z., Davis, S.J., Feng, K., Hubacek, K., Liang, S., Anadon, L.D., Chen, B., Liu, J., Yan, J. and Guan, D., 2016. Targeted opportunities to address the climate–trade dilemma in China. Nature Climate Change, volume 6 number 2, page 201

Luzzati, T., Orsini, M. and Gucciardi, G., 2018. A multiscale reassessment of the Environmental Kuznets Curve for energy and CO2 emissions. Energy policy, 122, pages 612 to 621

Mikayilov, J.I., Hasanov, F.J. and Galeotti, M., 2018. Decoupling of CO2 emissions and GDP: A time-varying cointegration approach. Ecological Indicators, 95, pages 615 to 628

Mohapatra, S., Adamowicz, W., and Boxall, P., 2016. Dynamic technique and scale effects of economic growth on the environment. Energy Economics, volume 57, pages 256 to 264

Moran, D. and Wood, R., 2014. Convergence between the Eora, WIOD, EXIOBASE, and OpenEU's consumption-based carbon accounts. Economic Systems Research, volume 26 number 3, pages 245 to 261

Organisation for Economic Co-operation and Development., 2015. Carbon Dioxide Emissions embodied in International Trade

Office for National Statistics, 2019[a]., Energy use: by industry reallocated to final consumer and energy intensity

Office for National Statistics, 2019[b]., Carbon dioxide emissions intensity by industry

Office for National Statistics, 2019[c]., Energy use: total

Office for National Statistics, 2019[d]., Greenhouse gas intensity, provisional estimates, UK: 2017.

Office for National Statistics, 2019[e]., Atmospheric emissions: greenhouse gasses by industry and gas

Rezaei, F., Yunus, R., Ibrahim, N.A. and Mahdi, E.D., 2008. Development of short-carbon-fiber-reinforced polypropylene composite for car bonnet. Polymer-Plastics Technology and Engineering, volume 47, number 4, pages 351 to 357

Ruffing, K., 2007. Indicators to measure decoupling of environmental pressure from economic growth. Sustainability Indicators: A Scientific Assessment, 67, page 211

Sheu, J.J., Yu, C.H. and Wang, J.K., 2017. Die Designs of Cold Roll Forming Process for Car Bumper Using Advanced High Strength Steel. Procedia engineering, 207, pages 1308 to 1313

World Bank., 2019. GDP (constant 2010 US$)

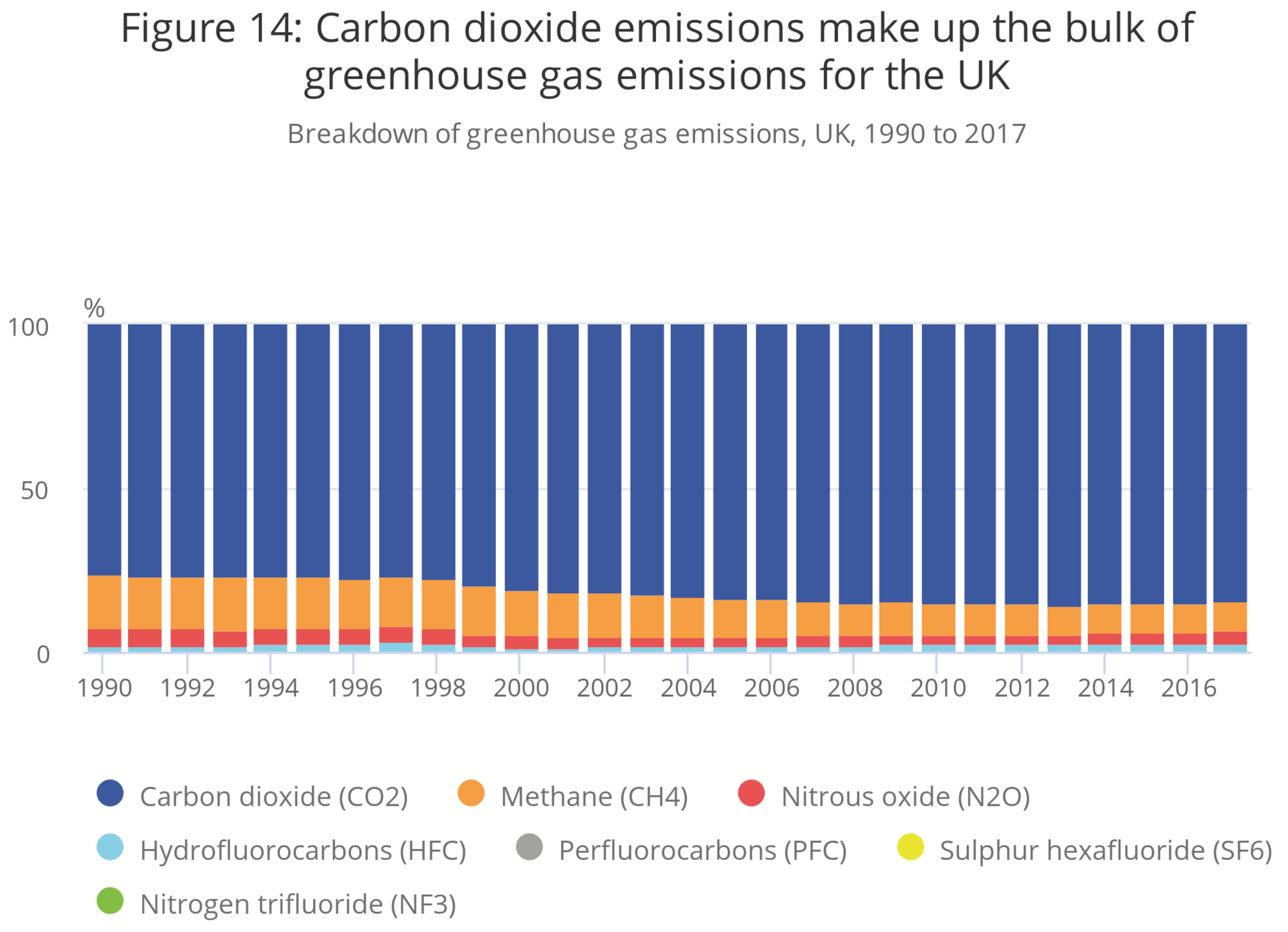
World Resource Institute., 2017., Historical Emissions

Yandle, B., Vijayaraghavan, M. and Bhattarai, M., 2004. Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications. A Primer, PERC Research Study 02-01

11 . Appendix A: Total UK greenhouse gas (GHG) emissions

Figure 14: Carbon dioxide emissions make up the bulk of greenhouse gas emissions for the UK

Breakdown of greenhouse gas emissions, UK, 1990 to 2017



Source: Office for National Statistics, 2019e

12 . Appendix B: Regression analysis

Table 1: Regression Analysis
Regression analysis of Environmental Kuznets Curve (EKC) model, 1850 to 2017

	(1)	**(2)**
	CO_2 Emission (Tonnes)	
Real GDP (Per head)	71,226.41***	49,696.78 ***
	(-3,620.371)	(-1,917.765)
Real GDP (Per head)^2	-2.129***	-1.181***
	(-0.118)	(-0.073)
Coal Consumption (Tonnes)		1.688***
		(-0.059)
Constant	87,700,000***	-74,300,000***
	(-20,400,000)	(-6,852,005)
Observations	167	167
R2	0.757	0.955

Source: Author's own compilation

Notes

1. Standard errors are in parentheses * $p < 0.1$ ** $p < 0.05$, *** $p < 0.01$. Robust standard errors were used.
Back to table

13 . Appendix C: Turning point calculation

A standard quadratic function is:

$$f(x) = \beta 1x + \beta 2x^2 + c$$

when a0, a parabola, such as the EKC, is shown.

The standard EKC regression model is:

$$(E)it = \alpha i + \beta 1(GDP/P)it + \beta 2(GDP/P)^2 it + \varepsilon it$$

where E is CO_2 emissions, P is population, GDP is gross domestic product and is a random error term.

Thus, the “turning point” (vertex) is calculated using:

$$x = -\beta 1 / 2\beta 2$$