Historical Energy Price Shocks
and their Effects on the Economy

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The purpose of this paper is to identify the changes in the impact of energy shocks on economic activity at different phases of economic development – with an interest in assessing if the economy's vulnerability and resilience to shocks improved. Using data on the United Kingdom over the last three hundred years, the paper replicates a method introduced by Kilian (2008) to disentangle supply, demand and speculative shocks. Once the shocks were identified, their influence on energy prices and GDP was tested using an 80-year moving average. The impact of supply shocks on GDP increased in the eighteenth century, fell to zero and then increased again during the second half of the twentieth century. The impact of aggregated demand shocks was relatively constant until the 1840s, dropped to zero and, then, increased throughout the twentieth century, peaking at the beginning of the twenty-first century – as these aggregate demand shocks have been generated by international (rather than domestic) energy markets. This suggests greater resilience with the economy's transition from biomass to coal, but possibly greater vulnerability with the transition to oil. However, because of a trend of decreasing shock magnitudes, GDP has been less affected by energy shocks since the mid-twentieth century, creating an illusion of declining vulnerability.

Keywords: energy prices; long run; economic impact, supply shocks, demand shocks

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1. Introduction

A nation’s long run economic success is highly dependent on its vulnerability and resilience to shocks (Balassa 1986, Romer and Romer 2004). Oil shocks have been seen as one of the main dampeners of economic growth since the Second World War. Especially since the oil crisis of the 1970s, economists have sought to identify their effects on the economy (Hamilton 1983, Kilian 2008).

Nordhaus (1980) outlined some of the key avenues through which oil prices can constrain the economy – principally, by raising energy expenditure (when price elasticities of demand are low) which raises the price of goods produced and reduces goods consumed, thus, harming GDP, as well as harming the balance of payments (when oil is imported) and generating inflationary pressures. Hamilton (1983) estimated a statistically significant relationship between oil price hikes and economic recessions between 1948 and 1981. Mork (1989) identified the asymmetry of the impact of oil price increases and decreases on GDP. Kilian (2009) showed that the source (i.e. supply- or demand-driven) of an oil price hike is crucial to its impact on output and inflation. While some studies have focused on the impact in developing economies (Schubert and Turnovsky 2011), the lessons from potential meta-analyses are inevitably limited by the features of cross-sectional studies.

Instead, one might be interested to know whether individual economies have become less vulnerable (i.e., the total impact) and more resilient (i.e., the ability to bounce back) to energy shocks through time and as they have developed. For instance, one might expect that economic development - for instance, the shift from an agrarian to an industrial to a knowledge economy – is enabling nations to become more capable of absorbing shocks. This might be because of a declining share of energy in production, more flexible labour markets or better monetary policies (Blanchard and Gali 2009). Dhawan and Jeske (2004) found that, since 1986, developed economies have become less vulnerable to oil shocks. The focus of most of these studies, however, has been on the post-Second World War period in mature industrialised economies.

To extend our understanding of a possible tendency towards declining vulnerability ad possibly greater resilience, the purpose of this paper is to estimate the changing impacts of energy shocks in the United Kingdom over the last three hundred years, from a predominately agrarian to a post-industrial economy. The purpose of this paper is to identify the evolution of the impact of energy shocks on economic activity at different phases of economic development. It uses the rich data available for the United Kingdom on economic growth and energy prices (such as Broadberry et al 2013 and Fouquet 2011) to estimate the changing relationship.

Naturally, given that the economy's dependence on oil has been relatively recent (i.e., after the Second World War), this study considers energy more broadly, which has played a crucial and increasingly acknowledged role in economic growth (Kummel et al 2002, Ayres and Warr 2004, Allen 2009, Stern and Kander 2012). This broader perspective is also valuable given that the fuel mix in many economies is shifting towards natural gas, and a focus on oil at the expense of other energy sources might limit the value of these recent studies to interpret the vulnerability and resilience of future economies to natural gas (or even renewable energy) price hikes.

The following section reviews the literature on the impact of energy shocks on economic activity since the Second World War. The third section outlines the data used for this analysis. The fourth section explains the methodology used, based on Kilian (2008), and identifies the sources and size of the energy shocks over the last three hundred years. The subsequent section presents the evidence on how the impact of these shocks has changed over that time. The final section tries to draw the lessons from this historical experience for developing and developed economies.

2. The Impact of Oil Prices Shocks on the Economy since 1948

The literature boom about the influence of oil prices on GDP was initiated by Hamilton´s 1983 empirical study, which used a six-variable system for testing the influence of oil prices on macro-economic aggregates. His regression analysis of oil prices on GDP and unemployment in the US resulted in a significant impact coefficient, also when correcting for other macro-economic aggregates. These findings were confirmed by Burbidge and Harrison (1984), Gisser and Goodwin (1986), Mork (1989), Ferderer (1996) and others. Corresponding studies by Mork et al. (1994), Papapetrou (2001), Lee et al. (2001), Jiménez-Rodríguez and Sanchez (2005) & Lardic and Mignon (2006) for other major OECD countries and by Cunado and Gracia (2005) for six non-OECD Asian countries revealed that the negative oil price-GDP effect prevails in virtually all industrialized and industrializing economies, even in oil exporting countries like United Kingdom (since 1980; Mork et al. 1994) and Malaysia (Cunado & Gracia 2005). Also, the effects seem to be surprisingly similar across developed countries.

Moreover, Mork (1989, 1994) as well investigated symmetry regarding the oil-GDP effect: since the negative response of GDP to oil price increases was of a significantly higher magnitude than the positive response of GDP to oil price decreases during the 1967-1992 period, Mork concluded that a asymmetric model is necessarily to investigate the effect properly. Mory (1993) and Lee et al. (1995) confirmed the existence of asymmetry with the finding that oil price decreases had no impact on the US economy, while Lardic and Mignon (2006) determine that asymmetric cointegration is of major relevance in explaining the impact of oil price shocks in his twelve European sample countries.

According to the majority of studies, the impact coefficient of oil prices on GDP declined strongly over time. Hamilton (1983, 1996) found a significant higher impact coefficient for the period 1948-1973 compared with the period after that. Blanchard & Gali (2009) found a reduced impact coefficient in the early 1980s, while Kilian (2008) and Baumeister & Peersman (2008, 2012) found a strong decline in impact coefficients of oil prices on GDP in the mid-1980s. While Hamilton (1996) suggests that the reason for this declining impact is the higher level of overall inflation during the 1973-1980 period and rejects the idea that a structural break has taken place, McConnell and Perez-Quiros (2000), Baumeister & Peersman (2008, 2012) and Kilian (2008) propose the existence of a structural break in the oil-GDP effect during the 1980s. Continuously, various authors tried to find the explanation for this widely accepted ‘structural break’ of the oil-GDP effect. Proposed explanations are the declining share of oil expenditures in GDP, declining wage ridigities, improved response of monetary policy (Blanchard & Gali 2009, Bernanke 2004), the sectoral composition of GDP (Maravalle 2012), the terms of trade balance (Maravalle 2013), differences in overall macroeconomic uncertainty (van Robays 2012), or a change in the origins behind an oil price surge (Kilian 2008, 2009 & 2011, Melolinna 2012) and the difference between the inflationary effects of these origins (Chen 2009).

By looking at the different origins between oil price surges, Kilian (2008) initiated a revolution in the oil-GDP debate. While earlier work regarded oil price shocks to be exogenous and the result of supply distractions, Kilian proposed a three-variable endogenous model including oil production, real economic activity (using a business cycle indicator) and oil prices to disentangle three different shocks that could have an impact on energy prices:

- crude oil supply shocks (due to primarily exogenous events);
- aggregate demand shocks (for most industrial commodities in the global market);
- oil-market specific demand shocks (that are specific to the global crude oil market, usually based on fear of future events that might cause oil prices to change; they are also known as precautionary demand or speculative shocks).

Although several different approaches of this breakdown have been proposed by recent papers (e.g., Lutkepohl 2012, Melolinna 2012), the original breakdown proposed and continuously improved by Kilian (2008, 2009, 2012) forms the core of the existing consensus. His conclusions are that while oil prices are affected considerably by demand effects and to an even larger extent by speculation, the effects of supply shocks on oil prices are relatively low. The effects of supply shocks are a little more disruptive for GDP during the first year after the shock, while oil-specific demand shocks and aggregate demand shocks (more significant) are more disruptive for GDP after about two years. Aggregate demand shocks actually improve GDP during the first year as the positive effects for GDP offset the negative effects of the oil price increase that it leads to. Finally, he measured that the cumulative effect of oil supply shocks on oil prices since 1975 are much smaller than those of aggregate and oil-specific demand shocks, contradicting Hamilton´s conclusions and invalidating his methodologies that assume oil price variation to be exogenous. In an earlier paper (Edelstein and Kilian 2007), Kilian also rejected the significance of asymmetry in the oil-GDP effect. According to this paper, the acceptance of the significance of this asymmetry by earlier papers (Mork 1989, 1994; Mory 1993; Lee et al. 1995; Hamilton 1996, 2003) had to do with ignoring the 1986 US Tax Reform Act that very likely would have offset the positive effects that a strong decline of oil prices could have had in the same period.

The conclusion that the 2002-2008 oil price surge has been caused by aggregate demand rather than supply effects explains why it left to be unexplained by earlier research that tried to perform a direct VAR regression of oil prices to GDP. Hence, as it is likely that worldwide aggregate demand has a positive impact on as well GDP as oil prices, a regression between the two would not show the negative correlation like it did with the oil supply crises in the 1970s. Hamilton (2009) as well mentioned that a rapid growth of aggregate demand and speculation played a role in the 2002-2008 oil price surge next to stagnated supply from the conventional oil exporters. Using a ‘what-if’ method, he states that, in absence of the oil shock, US GDP would have risen by 3% instead of fallen during the recession that took off in late 2007.

Nearly all literature so far came to the interesting conclusion that the effect of an energy price increase on GDP is significantly larger than the share of energy expenditures in GDP would suggest. Economic theory has long struggled in attempting to explain this finding (Finn 2000). Therefore, simultanously with the discussion about whether and to what extend oil prices affected GDP, the channels of transmission regarding this causality have been investigated. Kilian (2008) mentions four different transmission mechanisms through which an increase in energy prices might affect GDP. We can roughly divide these four effects in two categories. One category that has to do with the actual function of energy in the economy. These effects are likely to be symmetric in response to variation of energy prices, as they are relevant for as well energy price increases as decreases: operating cost effect (for durables that use oil as an energy input, their demand and usage is dependent on the operating costs defined by the price of oil (see Hamilton 1988)); discretionary income effect (as demand for most energy services nowadays is expected to be inelastic, changes in energy prices will have an effect on total income with consequences for consumption of other goods).

The other category consists of effects that have to do with human behaviour and expectations. Therefore, catching these effects in conventional economic models is more complicated and as a result, they are harder to predict. For these effects, an asymmetric response of GDP to energy price variation is likely, as given the risk-aversion of human nature, these effects are expected be stronger in relation to energy price increases compared to energy price decreases: uncertainty effect (changing energy prices may create uncertainty about the future path of the price of energy, causing consumers and producers to postpone irreversible investments (see Bernanke 1983, Robert S. Pindyck 1991)); precautionary savings effect (in response to an energy price increase, consumers might smooth their consumption because they perceive a greater likelihood of future unemployment and the resulting income losses).

Using an economic growth model with capital, labor and energy as factors of production and integrating energy in the capital utilization formula, Finn (2000) found that an energy price shock can be considered as an adverse technology shock (in the Solow model), since it causes technological capital to produce below capacity levels. According his model, an increase in energy prices would cause GDP to decrease more than twice the amount as would be expected on behalf of the energy share in GDP. Using Swedish GDP and energy data for the period 1800-2000, Stern & Kander (2012) as well conclude that whenever energy becomes scarce (hence, energy prices increase), GDP will respond stronger than the share of energy expenditures in GDP when energy is abundant (hence, cheap). Thus, even when limiting ourselves to the actual function of energy in the economy, energy price shocks are expected to affect GDP stronger than the share of energy in GDP would suggest.

The second category of transmission channels, concerning the influence of risk-aversive human behaviour, could even strengthen the negative response of GDP to increasing energy prices on top of the previous explanation. Postponed investments and consumption smoothing cause GDP to be affected stronger than the share of energy expenditures would suggest. Moreover, conclusions of an asymmetric response of GDP to oil prices (Mork 1989, 1994; Mory 1993; Lee et al. 1995; Hamilton 1996, 2003) would suggest that the uncertainty effect is the dominant effect in the observations regarding the oil-GDP relationship, since this effect is based on the decline of investments as a result of energy price volatility in general rather than just energy price increases (although, as mentioned above, the significance of asymmetries can be questioned due to the 1986 US Tax Reform Act). Following this reasoning, regressions taking oil price volatility rather than oil price innovations as a explanatory variable for GDP have been performed for the US (Guo and Kliesen 2005) and several other oil-importing countries (Germany, Japan, India, South-Korea) as well as oil-exporting countries (Malaysia) by Rentschler (2013). For all countries, there seemed to be a significant negative impact of oil price volatility on GDP, which could also explain why even oil-exporting countries can suffer from oil price shocks as mentioned earlier. Given these findings, there are good reasons to believe that the effect of uncertainty has been of major influence concerning the influence of oil prices on GDP during the last decades.

As an attempt to analyse the effects of energy prices on the long term, this paper will replicate the breakdown of price innovations as presented by Kilian (2009, 2011) and apply it to British energy prices during for the period 1700-2008. We chose to replicate Kilian's method, not only because it seems to be the current concensus in the oil-GDP discussion, but also because it is easy to replicate for long-term data and it gives an interesting overview of the timing and relative magnitude of different shocks during 308 years of British history. Up to that, the 2002-2008 oil price surge is likely to be not the only case during the past three centuries where aggregate demand simultaneously boosted as well energy prices as GDP, thus a direct regression of energy prices to GDP would be invalid due to these events. The next section will go into detail about the data used for this approach. Section 4 deals with Kilian´s approach, breaking down the energy price innovations in supply, demand and speculative shocks. Section 5 gives the results of a regression of these different effects on energy prices and GDP. Section 6 concludes and discusses the results and implications.

3. Data

To study the historical impact of United Kingdom energy prices on economic activity at different phases of economic development, it is necessary to gather statistical information on different fuel prices and GDP for the period 1700-2008, as well as indicators for supply and demand in order to reproduce Kilian's (2009) breakdown of oil price innovations. The following is a summary of the sources and methods - more detail of the sources can be found in Fouquet (2008, 2011).

United Kingdom GDP is based on pulling together data from Broadberry et al. 2013, Mitchell 1988 and ONS 2010). The consumer price index data available from Allen (2007) enables GDP and prices to be broadly comparable across time and expressed in real terms for the year 2000. The price data, and indiciators of supply and demand will be presented in the following three sub-sections.

3.1. Price Data

The price series used in this topic are composed from a variety of data. All of the original price series for energy fuels are published and discussed by Fouquet (2011) and can be seen in Figure 1, along with trends in GDP. To replicate the existing oil price-GDP literature in this paper, however, we are interested in an aggregate price series for all different energy fuels. To calculate these series, we first created index numbers for the fuel prices of every different service[3] and weighted them on the expenditures on energy fuels of every service. We chose to use index numbers instead of taking an average of real fuel prices (weighted on expenditures), since different fuels can be of completely different values that are not directly comparable. For example, provender was about 12 times more expensive per energy unit than coal in the 19th century. Weighting the average values of primary fuels, a 5% decrease in the provender price would then overweigh a 20% increase of the coal price in the same year, even when expenditures on both provender and coal are equal (hence, with equal weights, the decrease in the coal price should outweigh the increase of provender price by a factor of four). Using index numbers however, the percentage change in prices is measured instead of the absolute change, resolving this problem.

After this step, we followed Kilian's (2008) approach, weighting the prices by the share of total energy expenditures in total GDP. Resulting is an index series that represents the accumulation of expenditure-weighted changes in energy prices over time. Since we want to measure the economic effects of energy price 'shocks' in this paper, we are interested in the annual deviations rather than the evolution of these price index series.

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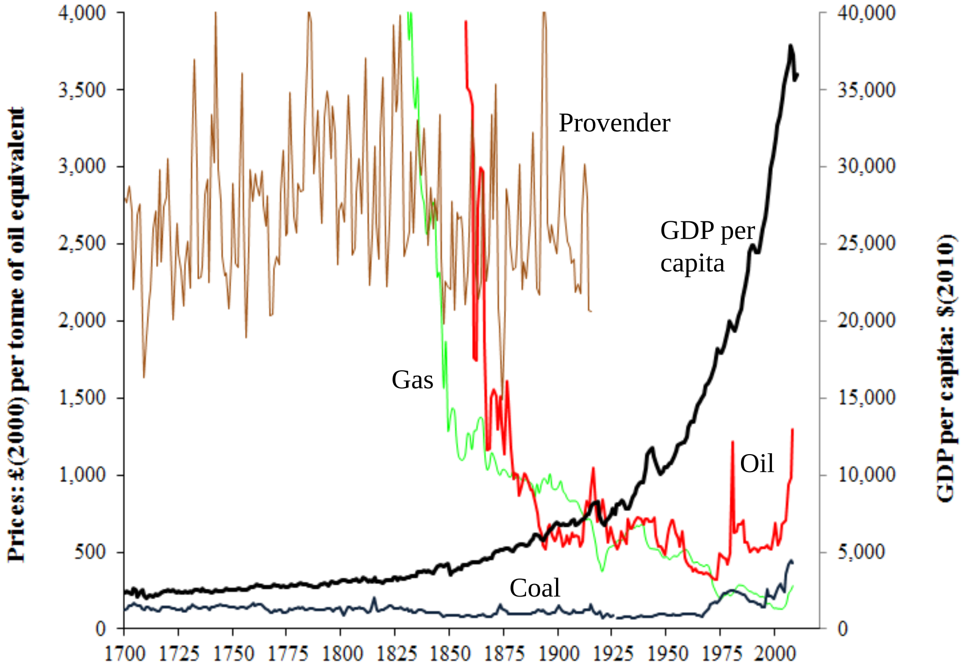
[3] As we divide the fuel prices indices by the service end-use, we measure the prices as paid by final users (after taxes) and thus not the prices of primary energy.



Source: Broadberry et al (2013), Fouquet (2011)

Figure 1. United Kingdom Energy Prices and GDP per capita (1700-2008)

The average price series generated for the current analysis looks paints a different picture than the index prepared in Fouquet (2011). For instance, the 308-year long trend in the current paper shows generally increasing energy prices while the switch from biomass fuels towards coal clearly decreased average energy prices over this period, as in Fouquet (2011). The explanation for this difference can be found in the method used, as explained above: since these price series measure the annual relative changes in the different fuel prices, weighted by expenditures on each fuel, they generally neglect the effects of a switch from one fuel to another. While these energy transitions clearly have an important effect on average fuel prices, they generally occur on the long term. However, since the goal of our paper is to measure the economic effects of energy price 'shocks', these long-term developments in energy prices are not too relevant in this case.

3.2. Supply Data

The supply index series in this paper was constructed using a variety of sources for each different fuel type. Per fuel type, the weight for the final indicator is based upon the share of expenditures on this fuel relative to the total expenditures on energy fuels. The expenditures are calculated by multiplying consumption with the 10-year moving averages[4] of the prices of each fuel.

Provender for working animals: consumption of food and provender can easily be estimated using human and animal population estimates. However, production data is harder to obtain. Due to extensive documentation by Broadberry et al (2013), it was possible to obtain an annual estimate for agricultural production in Great Britain for the period 1700-1870. In their data, they report an estimate for agricultural GDP in which price variation is filtered out. Using this index, it was implicitly assumed that the production trend is similar for Northern Ireland and that on average, variation in the annual production and price estimates is equally spread between the food and provender sector. For the period after 1870, production growth data is extrapolated. However, the share of provender in the total energy mix had already lost most of its significance by 1870.

Wood: For simplicity, we keep wood production equal to wood consumption over the whole period. Since wood production has not been very significant in the British energy mix since 1700, the assumption that wood is obtained whenever there is demand could be quite realistic for the UK. Consumption data is obtained from Fouquet (2008).

Coal: For the period until 1981, we only use estimates of coal production within the United Kingdom. Even though coal is an internationally tradable commodity, accurate world coal production estimates are absent for the pre-1981 period. Also, the UK was a net exporter of coal until 1984, so mainly homeland production was relevant for British coal supply until 1981. For the period after 1981, world coal production estimates are used as the worldwide market became important for UK supply purposes. This data is obtained from the BP Statistical review 2011.

Petroleum: For the complete time series, we used the world oil production data from the JODI database[5]. Doing this, we assume that since oil is a relatively easy-to-transport energy source, production numbers throughout the world are relevant for the UK.

Natural gas: Until 1970, nearly all gas consumed in the UK was obtained from coal in the form of Town Gas. Since the production of town gas from coal is an industrial process, we use coal production as a proxy for town gas production. From 1970 on however, when natural gas use increasingly replaced town gas use in the UK, we use the natural gas

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[4] Ten-year moving averages were used in the calculation of fuel expenditures to remove most of the influence of price volatility in the weighting procedure.

[5] Available at http://www.jodidata.org/.

production estimates of the UK for the share of natural gas in the total gas mix (100% from 1976 onwards). For most of the period since 1970, the UK was nearly producing all its natural gas within its borders. The data on natural gas production in the UK are again obtained from the BP Statistical review 2011.

3.3. Aggregate Demand Data

The measure of aggregate demand is subject to a lot of discussion. In his papers, Kilian uses worldwide dry cargo shipping rates as an indicator of aggregate demand. His reasoning is that since the supply of shipping is very price-inelastic, the variance in the price of shipping is a good indicator for the worldwide business cycles. In an upwards cycle, oil prices are expected to go up, but the negative effects of these higher oil prices on GDP could be offset by the positive effects that are initiated by the worldwide business cycle. This choice however has not gone unnoticed and it already received some critics. Melolinna (2012) for example argues that shipping freight rates are positively related to oil prices, while Kilian assumes a negative influence of oil prices on aggregate demand. Except for these critics, we do not have data on worldwide shipping rates back to 1700.

Also, it is not desirable to use a worldwide estimate of aggregate demand for the full period of our project, as aggregate demand outside the UK had little influence on energy prices and other economic aggregates in the UK for the majority of our sample. For that reason, we used 4 different gross demand indicators, dependent on the relevant region for a certain fuel during a certain period. The 4 regions and their assumed relevance in sense of fuel demand (influencing UK aggregates) are given in table 1. Most of the splits in the data between regions are already clarified above in the supply data. Besides these clarifications, we used an aggregate demand indicator for Europe and Western offshoots together for the oil part until 1965, since an oil-consuming world aggregate demand indicator could only be constructed from 1965 onwards and the big majority of oil demand until 1965 came from Europe and North-America.

A variety of different variables were tried as an indicator of aggregate demand. The most important feature of this indicator should be that it shows the ups and downs of the business cycle. For that reason, we finally decided using GDP data (aggregated for each country block) and used the Hodrick-Prescott Filter (using $\lambda = 100$, following Backus and Kehoe (1992)) to filter out the business cycle from this GDP data. Taking these four business cycle series together, weighted correctly on the relevant energy sources consumed in the UK, a final business cycle indicator resulted, being an indicator for (relevant) aggregate activity.

Table 1. Split of demand data into different regions by relevance for UK consumption

Regions: *Fuels:*	UK	Europe + Western offshoots	Oil-consuming world	Coal-consuming world
Biomass (provdender & woodfuel)	Full period	-	-	-
Coal	Until 1983			From 1983 onwards
Petroleum		Until 1965	From 1965 onwards	
Natural gas	Full period			

4. The Shock Analysis

As explained in the introduction, we will use our data to distinguish shocks in the supply of energy fuels, shocks in aggregate demand for commodities and shocks in the price of energy that cannot be explained by supply or demand shocks. In making this distinction, we can test the correlation between these resulting shocks on other variables like energy prices and GDP.

4.1. Methodology to identify shocks

The first step in our approach was to define all the supply, demand and speculative shocks through the analyzed period from 1700 to 2008. We used the same method as in Kilian & Murphy (2011), considering a fully structural oil market VAR model of the form

$$B_0 y_t = \alpha + \sum\nolimits_{i=1}^{2} B_i y_{t-j} + \varepsilon_t$$

where ε_t is a vector of orthogonal structural innovations and $y_t = (\Delta prod_t,\ rea_t,\ \Delta rpe_t)$ contains annual data on the percent change of energy production ($prod_t$), the index of real economic activity representing the relevant business cycle (rea_t) and the percent change in real energy prices (rpe_t). The vector ε_t consists of a supply shock, a shock to aggregate demand in the economy and a shock to energy prices that is not explained by variation in supply or demand, which we call a speculative shock. To identify these different shocks we use identification restrictions such that e_t can be decomposed according to $e_t = A_0^{-1}\varepsilon_t$:

$$e_t \equiv \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{\Delta rpe} \end{pmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\sup ply-shock} \\ \varepsilon_t^{demand-shock} \\ \varepsilon_t^{speculative-shock} \end{pmatrix}$$

In his initial version of the model, Kilian (2008, 2009) fixes the values of b_{12}, b_{13} and b_{23} to zero, as he postulates a vertical short-run supply curve of crude oil. In other words, he assumes that oil supply cannot respond to aggregate demand and oil price innovations and that real activity can also not respond to oil price innovations within one month. Although these assumptions are reasonable on a monthly basis, they are surely not realistic using annual data. That is why we used the method described in Kilian and Murphy (2012), in which he changed this assumption. Instead of fixing b_{12}, b_{13} and b_{23} to zero, he introduced a method of sign-identification to identify supply, demand and speculative shocks based on logical economic reasoning. In addition, Kilian and Murphy (2012) imposed bounds on the oil supply elasticity to limit the amount of resulting admissible models, based on historically observed maximum values of these (monthly) elasticities.

Table 2 gives the sign-identification scheme that we used to identify energy supply shocks, aggregate demand shocks and speculative shocks in our analysis. These sign restrictions are based on logical assumptions on the movements of the different variables as a response to the three different shocks. This way, an energy supply shock is identified if during one year, energy production declines and energy prices increase. For this shock, we are agnostic about the sign of innovations in real activity. An aggregate demand shock is identified if during one year real activity increases and energy prices increase as well. Hence we are agnostic about the sign of innovations in energy production in the identification of aggregate demand shocks. Since we assume that speculative shocks are shocks in the price of energy that are not the result of declines in energy production or increases in real activity, we identify them when energy prices increase, real activity decreases and energy production increases during the same year. For this reason they can also be considered as the residual shock, since they are identified as shocks in energy prices that are not explainable with the data we use in the model.

Table 2. Sign restriction from impulse responses

	Energy supply shock	Aggregate demand shock	Speculative shock
Energy production	-	+/-	+
Real activity	+/-	+	-
Energy price	+	+	+

These restrictions do not identify the shocks uniquely, but result in a large set of admissible shock matrices. As according to Kilian and Murphy (2012), every matrix that results into the variance-covariance matrix of the VAR model when multiplying it with its own transpose is an admissible shock matrix. Therefore, to minimize the level of uncertainty regarding the actual shock matrix, the main task is to limit the number of admissible matrices according to logical economic reasoning. By using the sign identification matrix in Table 2, 5,8% of all randomly generated rotation matrices turned out to be admissible to derive a shock-matrix[6]. A higher percentage of admissible rotation matrices also causes higher uncertainty about the actual shocks. Therefore, we try to minimize this percentage by imposing more restrictions on the identification of admissible matrices. This is possible as long as these restrictions are based on valid economic reasoning, so that they do not cancel out any truly possible shock matrices. Similar to Kilian & Murply (2012), we impose restrictions on the levels of supply elasticity to innovations in energy prices. Since we are working with annual instead of monthly data, our boundaries cannot be as strict as those imposed by Kilian & Murphy. Therefore, we did only assume that within one year, supply must be at least inelastic (i.e. an elasticity below 1) to shocks in energy prices. Such a limit, which is perfectly viable by economic reasoning, already decreases uncertainty about the actual shock matrix by 36%[7].

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[6] We used MATLAB to multiply 500.000 orthonormal rotation matrices with the recursively identified lower-triangular Cholesky decomposition of the variance-covariance matrix of the VAR model residuals (e_t), leaving around 29.000 admissible rotation matrices. This method is explained in detail by Kilian and Murphy (2012).

[7] By restricting the numbers of b_{12} and b_{13} to be lower than respectively b_{32} and b_{33} when deriving the admissible matrices using MATLAB, around 18.500 matrices (instead of 29.000 matrices) out of 500.000 orthonormal rotation matrices are left to be admissible shock matrices.

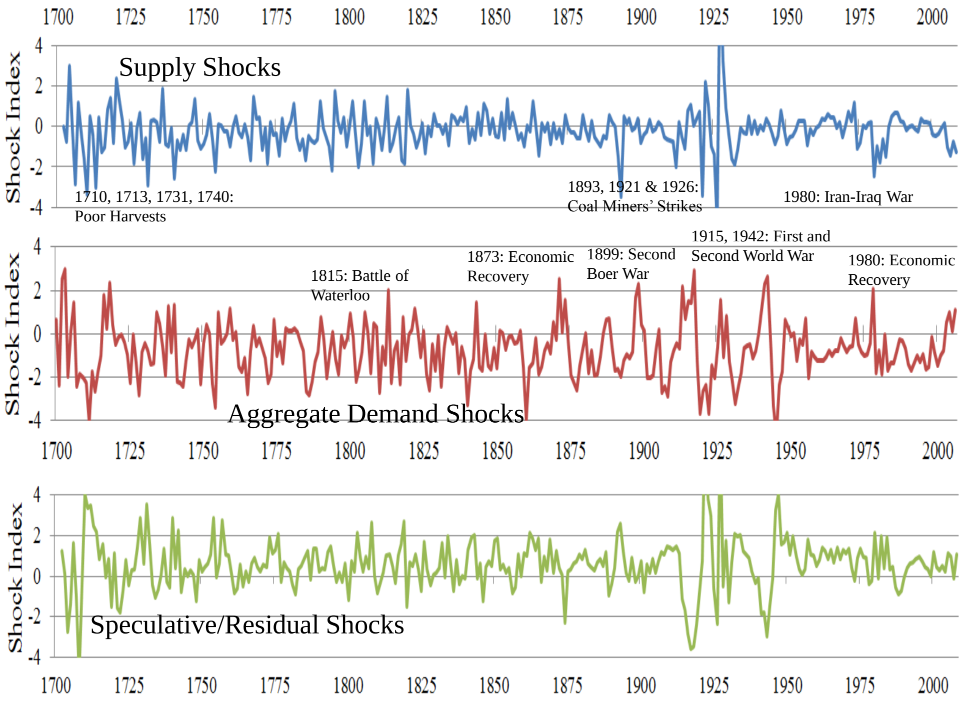
Although all of these resulting admissible models is theoretically equally viable, this large set of admissible shocks was narrowed-down to only one shock matrix for practical reasons concerning the final goal in Section 5. This unique shock matrix was identified by calculating the median value of each matrix entry and then by selecting the rotation matrix which had the smalles difference to the median entry values, calculated by the minimum sum of squares. Of the resulting closest-to-median rotation matrix, most of the values were statistically significant (on a 95% confidence interval), calculated using the standard deviation from the set of admissible rotation matrices. Here, 20,000 values for each entry were obtained, and the median entries were more than twice the standard deviation of these 20,000 values. Just the values of the agnostic entries, b_{12} and b_{21}, were not statistically significant. Since the final median matrix was in fact one of the admissible shock matrices closest to median, multiplying this matrix with its transpose gave the variance-covariance matrix of the model, in accordance with the conditions for a viable shock matrix.

Since the method above, as introduced by Kilian (2008, 2009) and Kilian and Murphy (2012), is initially designed for analyzing monthly data, there might be doubts about the robustness of our results on annual data. However, even with monthly data there can be a situation in which energy prices increase simultaneously with a decrease in energy production, while the actual cause of the energy price increase is not the decrease in production. In such a situation, an energy supply shock is identified, while it might as well be a result of coincidence. As Lütkepohl & Netsunajev (2012) point out, there may be an omitted variables problem if only those variables are included in the empirical model that are described in the theoretical model. The chance that identified shocks are actually just following from a coincidence is even bigger with annual data.

On the other hand, there might be some advantage in using annual instead of monthly data for the shock identification results. In his final results, Kilian (2008, 2009) finds a surprisingly low historical impact of supply shocks on oil prices and a very large impact of specific oil demand shocks (speculative shocks). However, shocks in specific oil demand might in some cases catch effects that are actually related to supply shocks, through the role of precautionary demand and storage that occur when a supply disruption is expected through a ‘news shock’. Rizvanoghlu (2012) investigated this ‘news shock’ using a theoretical model. He concludes that a ‘news shock’ is always followed by a strong price increase and GDP decrease, while the long-term effects depend on whether the ‘news shock’ is followed by an actual supply disruption. If yes, the effects on prices (up) and GDP (down) are persistent and strong, while if not, the response of prices and GDP first overshoots the steady state level in a backward direction and within three months, GDP and energy prices are back to their steady state levels. Since the ‘news shock’ and the actual supply disruption often occur in different months (but with a high probability during the same year), the chance that a supply disruption is captured by a ‘speculative shock’ instead of a ‘supply shock’ is smaller using annual data than when using monthly data.

4.2. Overview of Shocks

An overview of the shocks estimated using the method above can be seen in Figure 2. There has been a distinct evolution in the nature of supply shocks. From 1700 to 1820, there was broadly one major shock (i.e., near or below minus two) per decade. The transition away from biomass towards coal (see Figure 3) ushered in a period of stable supply (with less frequent and, on average, weaker shocks in the nineteenth and twentieth centuries). However, by the end of the nineteenth century, a series of very strong supply shocks were experienced. The post-Second World War era was one of supply stability interrupted only by two distinct (but, in historical context, modest) supply shocks – in 1980 and between 2006 and 2008.



Source: Authors’ estimates

Figure 2. Energy Price Shocks by Factor, 1700-2008

Table 3 provides an overview of all supply shocks with an absolute value of two or higher ordered by their probable cause - the average shock had a magnitude of 0.75. Two well-known shocks (the oil crisis of 1973-4 and the coal miners' strike of 1984) are included in grey, because they were below an absolute value of two.

Table 3. Energy supply shocks and probable causes for these shocks

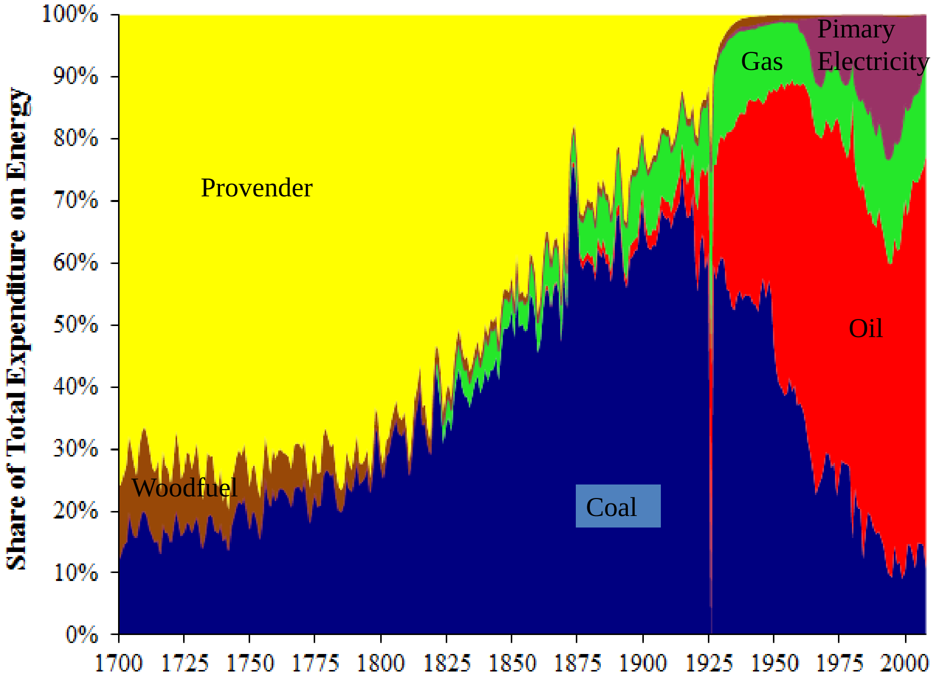
Supply shocks	Probable cause
1710, 1713, 1731, 1740	Agricultural reasons / crop failures
1893, 1921, 1926, 1984	Coal miners' strikes
1974, 1980	Oil crises

Source: Authors' estimates.

Since an aggregate indicator of energy is used in this study, the supply of energy is dependent on the weighted growth rates of every source of energy used. During the last three centuries, different energy sources have dominated at different times (Fouquet 2008). Figure 3 shows the distribution of total expenditures on primary energy sources in the UK since 1700. During the eighteenth century, provender was the most dominant source of energy for power. By 1700, coal had become the main source of heating, especially for domestic heating, although not yet for iron production (Fouquet 2008). Coal became the main source of power during the nineteenth century. In the twentieth century, oil became dominant for transportation and more recently natural gas for heating. Therefore, energy supply shocks are usually caused by a shock in the supply industry of the most dominant fuel. This has tended to create three different types of supply shocks, as visible in Table 3.

During the eighteenth century, agricultural factors like crop failures had an important impact on provender supply and therefore on total energy supply. During that century, four of these events generated major supply shocks. As the energy market changed, so did the events causing supply disruptions. Since most of the British economy was dependent on coal by the end of the nineteenth century, the first big coal miners' strike in 1893 led to a large disruption of energy supply. Subsequently, the strikes in 1921 and 1926 also led to very strong shortages (Church 1987). In 1984, when the economy was dependent on oil for transportation and natural gas for heating, the coal strike had a substantially weaker impact, but still influenced average energy prices, as coal generated most of the UK's power.

Meanwhile, the oil crises associated with unrest in the Middle-East led to a considerable supply shock in 1974 and a very large one in 1980.



Source: Fouquet (2008), Fouquet (2011)

Figure 3. Share of Primary Energy Expenditure in the United Kingdom, 1700–2008

Aggregate demand shocks experienced a broadly opposite experience. Except for a few major shocks (i.e. close or greater than two in Figure 2) in the early 1700s and then in 1815, important aggregate demand surges were very infrequent until the 1870s. At the beginning of the twentieth century, major shocks were relatively common and, throught the century, on average, the shocks were considerably stronger than before. However, the second half of the twentieth century only experienced one major aggregate demand shock, in 1980.

Aggregate demand shocks were driven by completely different factors. Indeed, the type of energy source used did not matter much for the existence of aggregate demand shocks, although which energy source used might determine whether the aggregate demand shock fed though into a price increase. Instead, the state of the economy was the driver of these shocks.

Significant demand shocks were observed in times of warfare, as they generated unusual and intensified demands for energy sources (see Table 4). The wars that had the most significant effects on aggregate demand were the War of Spanish Successsion (especially, 1704-5) and the Second World War (here, 1943-4). The Battle of Waterloo in 1815, the second Boer War in 1900 and the First World War (particularly 1915) also appear to have been important (see also Figure 2).

Table 4. Aggregate demand shocks and probable causes for these shocks

Aggregate demand shocks	Probable cause
1704-5, 1815, 1900, 1915, 1943-4	Warfare
1720, 1873, 1919, 1980	Strong Economic Growth

Source: see text above.

There were also years of civilian economic growth (1720, 1873, 1919 and 1980) that appear to have fed through into pressures on resources and increasing energy prices. In the case of 1720 and 1980, it seems that the rise in economic activity was in the preceding year, and there was a lag in their influence on prices.

Finally, ‘speculative’ shocks are estimated as the change in price not explained by changing supply or demand. Often, these are described as shocks associated with precautionary demand behaviour in which consumers or speculators hoard energy in the anticipation of future supply shortages (Kilian 2008). Both, major positive and negative ‘speculative’ shocks coincide with supply or aggregate demand shocks. This indicates that they do reflect some form of extended reaction to other ‘fundamental’ shocks.

5. Evolution of Shock Effects

The purpose of this paper is to analyze the economic effects of energy price shocks from a long-term perspective. As such energy price shocks can be caused by different mechanisms (i.e. energy supply, aggregated demand or speculation) and since GDP responds differently depending on the mechanism behind the shock, we chose to analyze the economic effects by breaking down the energy price shocks into the three different types.

5.1. Influence of Shocks on Prices

First of all, it is important to note that the identified supply and demand shocks are not directly related to energy prices[8]. Even if a supply or demand shock has not led to any energy price innovation by itself, it is still recorded as a shock, since it is possible that the energy price innovation that should follow from this shock has been offset by another simultaneous shock. That is why we need to perform tests on whether these shocks actually influenced energy prices.

In Section 3.1 it was explained that in the price series used in the model, we weighted the prices by the percentage of energy fuel expenditures in total GDP. While this is a necessary condition inside the model to estimate the shocks correctly, this method causes the resulting energy price series to be misleading: the positive and negative effects of demand shocks on fuel prices are strongly overestimated, as due to more consumption, both the fuel prices and the weights of these prices increase during these events. On the other hand, if price increases due to supply shocks are followed by a strong decline in energy consumption (which we see happening in many cases over the measured 300 years), this also decreases the weight of energy prices, detracting these price increases. Therefore, weighting the price changes on fuel expenditures strongly underestimates the effects of supply shocks. Since we want to see the effects of shocks on actual changes in energy prices rather than on those influenced by the consumption level, we used unweighted price changes as an dependent variable in the regression of shocks to energy prices.

Figure 4 gives an average value (for all 308 years) of the impulse response function of energy prices to each of the shocks. The results are estimated by the least-squares method, while inference is based on a wild bootstrap with 2000 replications (Similar to Kilian, 2009). This figure shows that the immediate response of energy prices to all three shocks is similar. That is, there is an initially large reaction to the shock and then, in later years, some response in the opposite direction. In other words, for all shocks, there tends to be overshooting to the shock in the first period.

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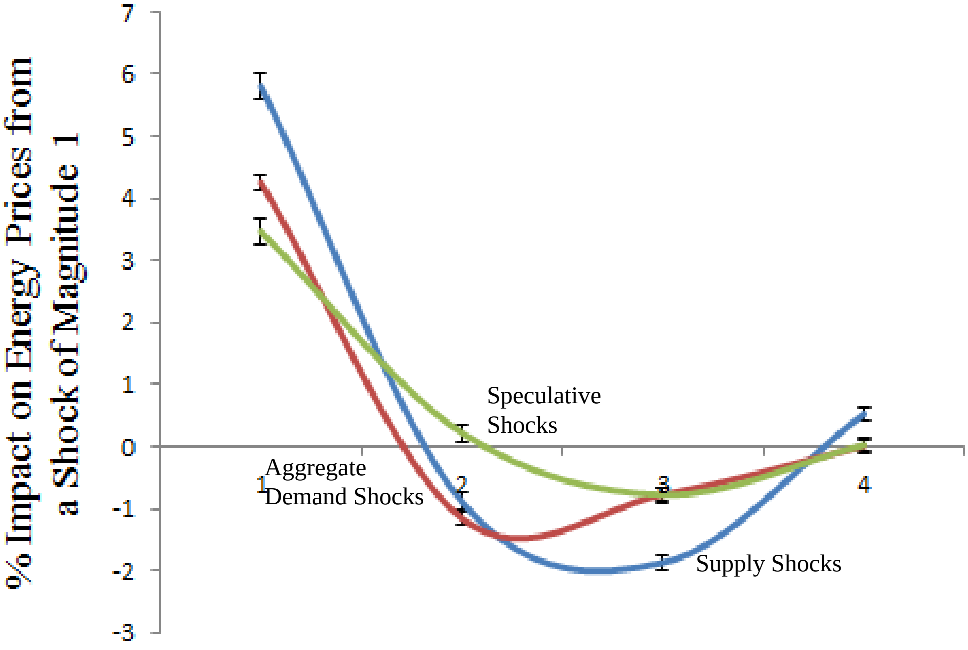
[8] However, speculative shocks *are* directly related to energy prices, as they are measured as price innovations not caused by any supply or demand shock.



Source: Authors' estimates

Figure 4. Immediate and Lagged Responses to Shocks of Magnitude 1 on United Kngdom Energy Prices (average over 1700-2008), with 95% Confidence Intervals

While this average graph shows the result over a total period of 308 years, we are interested in how this response changed over time. To analyze that, we performed similar estimates using moving 80 year periods (1700-1780, 1701-1781 etc) to construct a moving average of this effect (Fouquet and Pearson 2012). All the results were estimated using the least-squares method, and the standard deviations resulting from the same method[9] (as they differed very little from those resulting from the bootstrap method). We used periods of 80 years as it seemed to be the optimal length to ensure both a high flexibility in the resulting point estimates and low uncertainty levels.

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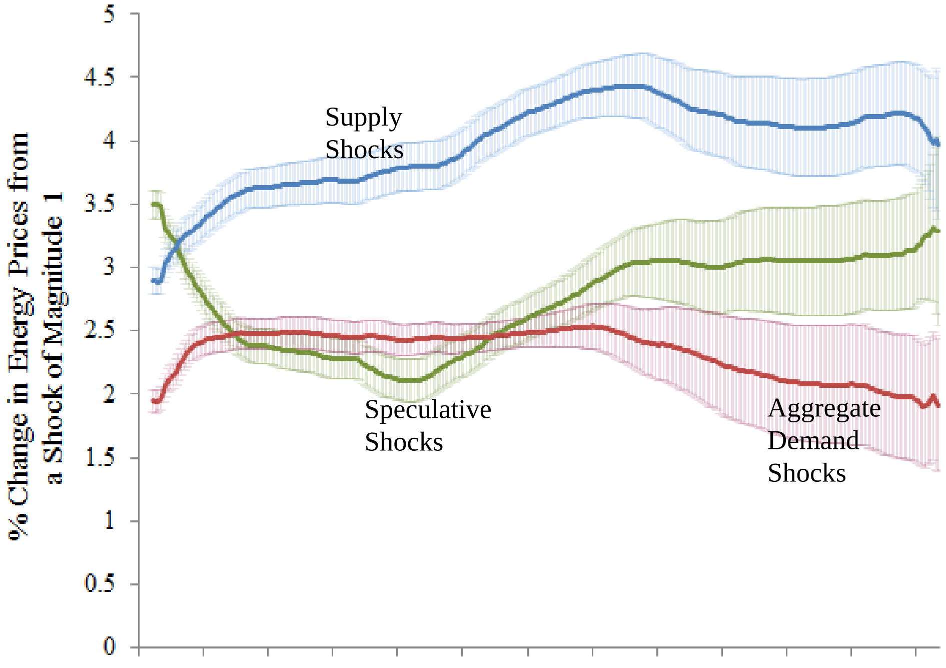
[9] As the results are presented as a sum of the effect over multiple years, we used the maximum standard deviation measured within that sum. In practice, the standard deviations of all the lags are very close to those of the immediate response.



Source: Authors' estimates

Figure 5. Accumulated Response of United Kingdom Energy Prices to Shocks, with 95% Confidence Intervals (1700-2008)

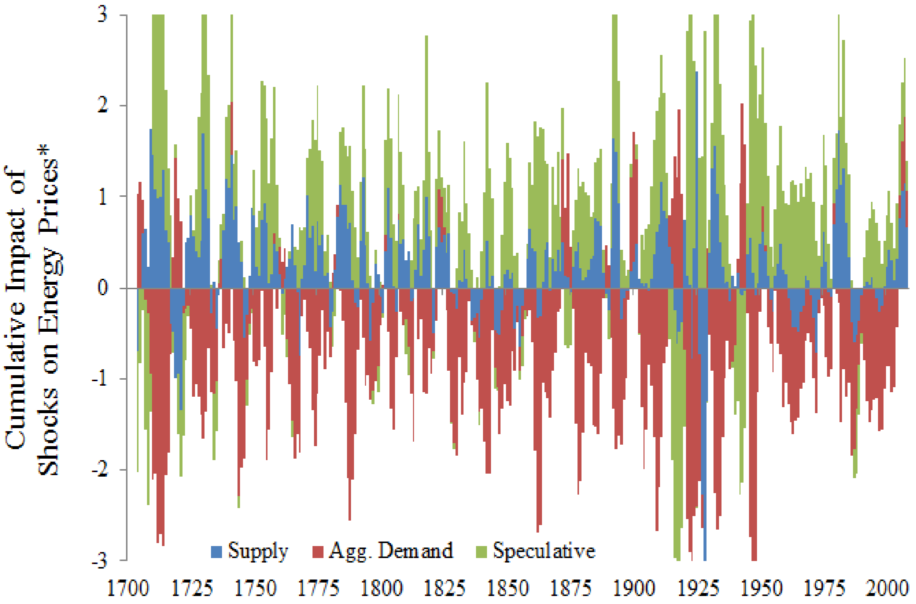
Figure 5 shows the resulting moving average of the effect of energy prices to shocks. These results represent the sum of the immediate impact and the three lags following these shocks (see Figure 4). The immediate impact of prices is quite similar for both supply and aggregate demand shocks (around a magnitude of 5), while a little lower for the speculative shock (about 4.5), and changes only modestly over the three centuries. Since, for each shock, there has been a lagged correcting response of energy prices in the opposite direction (as shown in Figure 4), the estimates in Figure 5 are smaller than the immediate impact. The accumulated or overall price response from supply and aggregate demand shocks are, apart from a small increase of the supply shock effect during the eighteenth century, surprisingly stable.

However, the effect of the speculative shock increases considerably with the transition to coal (through a large decrease in the measured corrective-effect of energy prices).

There are two possible explanations for the reduced corrective effect of speculative shocks compared with that of other shocks: first, as explained in section 4.2, many of the speculative shocks measured occurred simultaneously with supply and demand shocks, representing an immediate overshoot in the response of energy prices to supply and demand shocks. In these cases, there is no reason why the speculative effect would also overshoot the correction of the energy price during the period after the shock. Second, as explained in section 4.1, what we call the speculative shock is actually a residual price shock (i.e. energy price shocks not explained by supply or aggregate demand). Consequently, they might represent a price increase due to a structural change (like a fuel switch or any kind of taxation). This second explanation could also clarify why the corrective effect of speculative shocks declined sharply since 1830 onwards, as there were significantly more cases of a fuel switch (through a technology switch) and greater taxation of commercial fuels, such as coal, oil and natural gas, than for woodfuel or provender.

To give a rough idea of what has caused innovations in energy prices since 1700, Figure 6 represents the (3-year average) variation in energy prices during the past 300 years as a function of the estimated shocks (Figure 2) and their period-dependent influence on energy prices (Figure 5). The figure shows that except for some periods with large shocks (coal strikes, world wars and oil crises), the average magnitude of energy price innovations declined significantly through time: where shocks causing a 10% increase or decrease of energy prices occurred frequently in the eighteenth century, such shocks were rare in the twentieth century. However, during the last 35 years of the sample, most of the supply shocks occurred simultaneously with aggregate demand shocks, causing strong price shocks when adding up both effects. Kilian (2008) confirms that the oil supply shocks in the 1970s occurred simultaneously with strong aggregate demand shocks. Figure 6 also shows that different shocks were dominant during different periods and that speculative shocks indeed occurred simultaneously with supply and/or aggregate demand shocks in most cases (as speculative shocks, being on the background, just are sporadically visible in the figure).

However, one of the most striking observations is that aggregate demand is predominantly negative. That is, aggregate demand is not causing any increases in energy prices. This implies that, apart from a few phases over the last three hundred years, energy have had plenty of slack and markets have not been constrained by economic expansion.



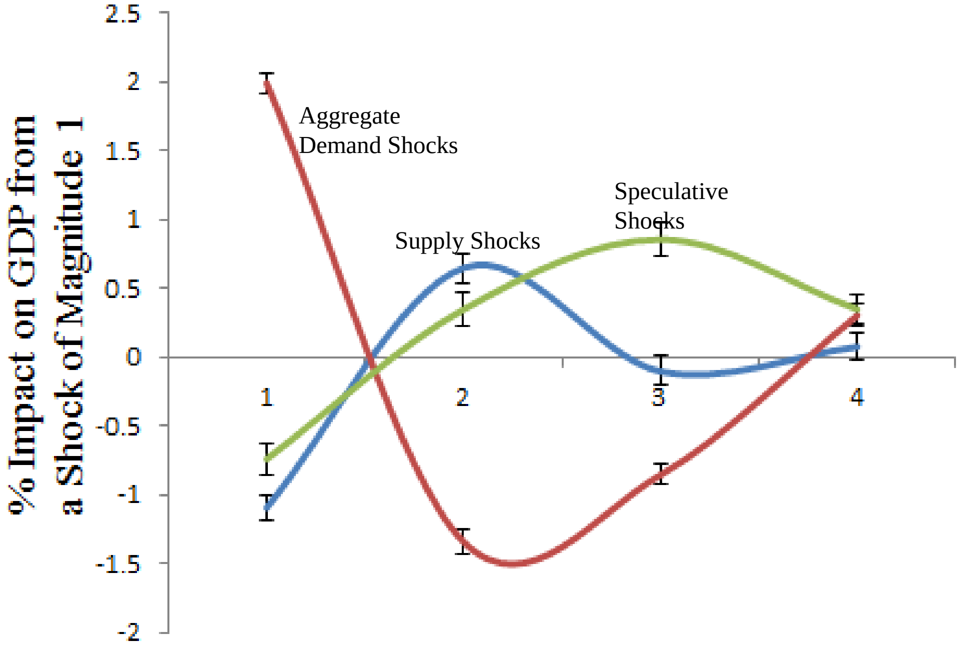
* Here, a negative supply shock is positive to sum shock effects on prices (conversely to Figure 2).
Source: Authors' estimates

Figure 6. United Kingdom Energy Price Variation Explained by Supply, Aggregate Demand and Speculative/Residual Shocks, 3-year average (1700-2008)

5.2. Influence of Shocks on GDP

The final purpose of the shock identification method is to isolate the different shocks to test their effect on GDP. A direct regression of GDP on energy prices would be strongly biased, as it would likely suffer from an omitted variables problem. Hamilton (1983) therefore included unemployment, domestic prices, wages, money supply and import prices to the regression of oil prices on GDP and as well tested for the unidirectional relationship. We did not replicate this method for two important reasons. Firstly, we do not have all this data on the UK back to 1700. Secondly, it is possible that a shock in aggregate demand is the main indicator for an energy price increase and in this case, we would expect an increase rather than a decrease in GDP, since the positive effect of increasing demand would likely offset the negative effect of higher energy prices. Consequently, if we do not filter them out, demand shocks will be mixed with energy supply shocks while both have a completely different effect on GDP.

Similar to our approach with energy prices, we first investigated how the response of the 3 different shocks on GDP generally took form during the past 300 years. Figure 7 gives a static visualization of the impulse response function of GDP for each of the shocks. The results are again estimated by the least-squares method, while inference is based on a wild bootstrap with 2000 replications.



Source: Authors' estimates

Figure 7. Immediate and Lagged Responses to Shocks of Magnitude 1 on United Kingdom GDP (average over 1700-2008), with 95% Confidence Intervals

Figure 7 confirms our expectation that the first response of GDP on aggregate demand shocks is significantly positive, while it is negative for supply and speculative shocks. However, the corrective effects of GDP to all shocks are much stronger than for energy prices: for both supply and demand shocks the sum of the lags gives a value near 0, while for speculative shocks it even gives a positive number.

For supply shocks, generally the whole negative impact is removed during the first year following to the shock. This makes sense, as a supply shock (leading to a price increase) is usually a short event that works as a temporary adverse technology shock, reducing the amount of capital utilization (Finn 2000). After the shock is over, capital utilization would come back to its earlier level and so does GDP according to this theory of supply shocks.

For aggregate demand shocks, however, the positive impact during the year of the shock has a longer lasting negative corrective effect, which is felt until 3 years after the shock. However, one must take care in interpreting this result. As aggregate demand shocks are measured by the business cycle (see section 3.3), a peak year in the business cycle is logically followed by a decline, so the response of GDP to aggregate demand shocks in Figure 7 is partly a self fulfilling prophecy[10].

The response to speculative shocks is also interesting: while Figure 3 indicates that the corrective effect of energy prices after a speculative shock is relatively low, Figure 7 shows that the corrective effect of GDP after a speculative shock is remarkably high and long-lasting. There are 2 possible reasons explaining this high corrective rate of GDP after a speculative shock. First, in many cases, a speculative shock represents the amount of overshooting in the response to supply and aggregate demand shocks. As it occurs mixed between both kinds of shocks, a regression would typically give a mix between the effects of both supply and demand shocks (though, historically they occurred mostly in combination with supply shocks). However, the positive effects that an increase in price has on efficiency might be largely caught by the speculative effect as it always implies an increase in energy prices. Second, speculative shocks might include any effects that could increase energy prices apart from the effect of supply and aggregate demand. A fuel switch through using different technology for example might have an increasing effect on energy prices, but might at the same time have a positive effect on GDP as the new technology might be more efficient or yield other qualitative advantages.

Just as we did for energy prices, Figure 8 shows the moving average of the final effect that the three different shocks had on GDP from 1700 to 2008 by summing up the responses of the four estimated lags. As well the point estimates as the uncertainty boundaries are calculated by using the same method as used for energy price (Figure 5), but now with GDP as a dependent variable.

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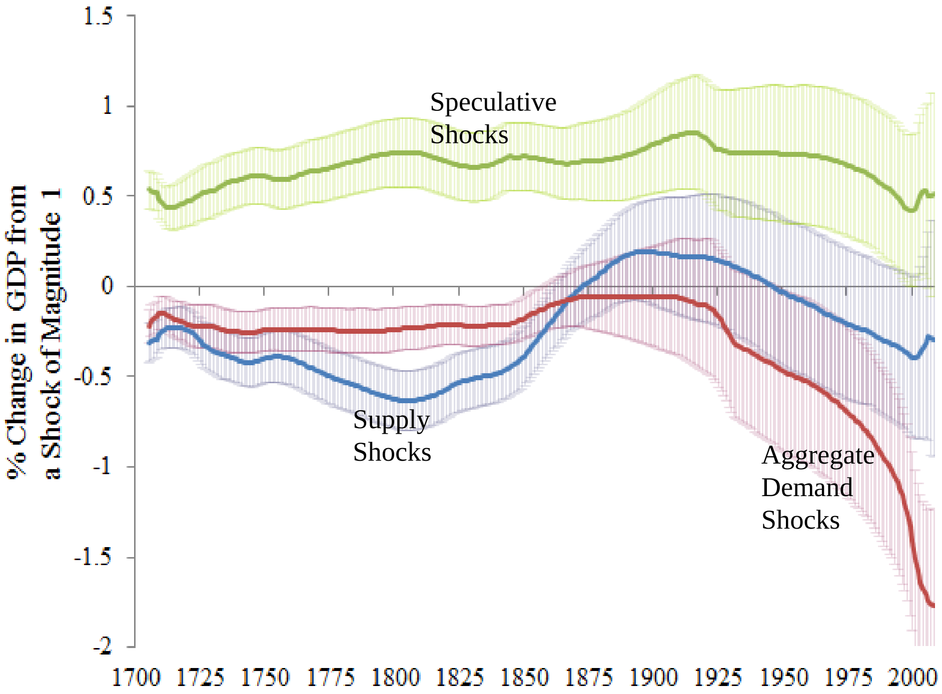
[10] The same effect would be in place in the results of Kilian (2008) as the aggregate demand indicator used in this paper as well measures the global business cycle through dry cargo shipping rates.

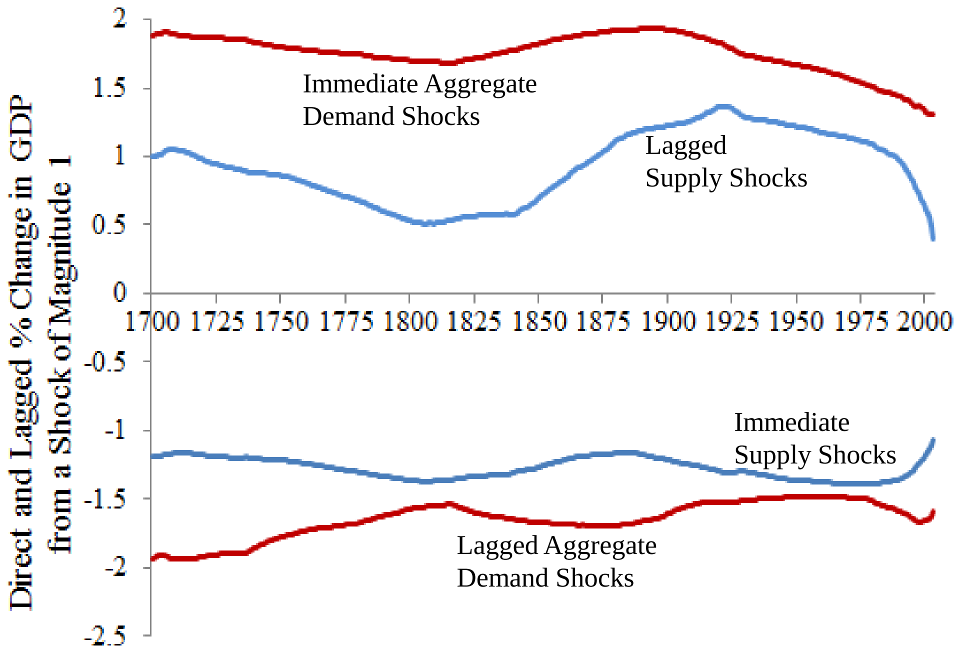


Source: Authors' estimates

Figure 8. Accumulated Response of United Kingdom GDP to Shocks, with 95% Confidence Intervals (1700-2008)

Figure 8 shows a negative effect of supply shocks during the agricultural age, becoming neutral from the mid-nineteenth to the mid-twentieth century. While the immediate response of GDP on supply shocks hardly varies during the entire period, it is the corrective effect that causes the change in the effect observed (see Figure 9). This is different for aggregate demand shocks, where a combination of a lower immediate response and a lower corrective effect cause the steep decline in the total response of GDP to aggregate demand shocks during the twentieth century. For speculative shocks, for which the positive effect on GDP increased strongly during the agricultural period while decreasing slightly from the mid-nineteenth century onwards, this evolution is almost completely caused by the variation of the immediate response of GDP to speculative shocks.

There might be a simple, yet unappealing explanation for the lower corrective effect of GDP to supply shocks during the agricultural era: while capital assets fuelled by fossil fuels (machines) can be sustained infinitely without being fuelled with energy, capital assets fuelled by agricultural products (humans and animals) can sustain only about a week without being fuelled with energy (food and feed). Therefore, using Finn's (2000) theory of energy price shocks as adverse technology shocks through declining capital utilization, a supply shock in the agricultural era (read: food/fodder shortage) would lead to a decreasing capital stock as part of the capital in place (read: working humans and animals) simply would die off due malnutrition. This effect could explain why the corrective effect (thus, after the supply shock is over) is lower in the agricultural era than in the post-agricultural era when supply shocks did not have any impact on the capital stock.



Source: Authors' estimates

Figure 9. Immediate and Lagged Response of United Kingdom GDP to Shocks (1700-2008)

The steep decline in the response of GDP to aggregate demand shocks into the twentieth century should again be interpreted carefully, as the relevance of real activity for energy prices shifts from the UK towards the rest of the world during the twentieth century (as explained in Section 3.3). Therefore, an aggregate demand shock in early periods is measured as a business cycle peak in the UK itself and so logically has a more positive impact on British GDP than a business cycle peak in the rest of the world. The declining response of GDP to aggregate demand shocks might therefore be partly or completely caused by a shift in the relevant real activity. Although this might be interesting by itself, such as when fuel markets became more international, this also created a larger mismatch between domestic business cycle peaks and high energy prices caused by international business cycle peaks, making these shocks economically more painful.

The peak in the early nineteenth century of the response of GDP to speculative shocks, caused by a period of a more 'soft' *direct* response of GDP to speculative shocks, is harder to explain. A possibility could be that in an economy where energy production is less concentrated (i.e. in an agricultural society, a far higher percentage of the population are net energy producers than in a fossil-fuelled society), speculative price increases are less harmful for GDP as such a redistribution of income not necessarily crowds out demand. When transforming to a fossil-fuelled economy however, speculative shocks will be increasingly beneficial to a small and rich share of the population owning these stocks of natural capital, crowding out demand of the poor.

Finally, as Figure 6 shows, there was a significant decrease in energy price shocks since World War 2. This decrease has not been caused by a declining vulnerability to energy price shocks (see Figure 5), but by smaller shock magnitudes (Figure 2). Similarly, the results in Figure 8 do not support the idea that GDP has become less vulnerable and more resilient to shocks over time. However, we cannot reject the statement made by Dhawan and Jeske (2006) and Kilian (2008) that vulnerability to energy price shocks has decreased in very recent periods (1988-2006 compared to 1970-1988), since the use of an 80-year moving average gives not enough flexibility.

6. Conclusion

The purpose of this paper was to analyze the effects of energy price shocks on GDP at different phases of economic development, by analysing United Kingdom data over the last three hundred years. To perform such an analysis, the method proposed by Kilian (2008) and Kilian and Murphy (2012) were used to disentangle supply, aggregate demand and speculative shocks. The shocks were identified and discussed in the context of historical events, such as poor harvests, miners' strikes or wars.

The results showed that there was considerable change in the effects of shocks on GDP over the past three hundred years (see Figure 8). The economy seems to have become a little less vulnerable (i.e., experienced a decline in the total impact) to supply shocks since the transition to coal. In fact, the results suggest that, between 1875 and 1950, the impact of supply shocks were positive, due to very strong lagged responses (see Figure 9) – this bouncing back from the immediate shock can be described as the economy being highly resilient to supply shocks. However, since the 1950s, these lagged responses have been in decline, suggesting a decline in resilience to supply shocks.

Similarly, the impact of aggregate demand shocks on GDP growth rates declined with the transition to coal, but the economy appeared to become more vulnerable with the transition to oil in the mid-twentieth century (see Figure 8). In general, this type of shock could be interpreted as a cost of the economy accelerating too quickly and overheating. With the transition to oil, the overheating was experienced at an increasingly global level and, often, there was a decline in the immediate positive gains to the domestic economy (see Figure 9).

More generally, however, the major reason why the economy has been less affected by supply and demand shocks since Second World War is simply that, apart from the price hike in 1980 and more modestly between 2006 and 2008, the shocks themselves have decreased significantly in strength (see Figure 6). However, we cannot reject the statement made by Dhawan and Jeske (2006) and Kilian (2008) that vulnerability to energy price shocks has decreased in very recent periods (1988-2006 compared to 1970-1988), since the use of an 80-year moving average limits this study’s ability to properly detect shorter-run changes.

Compared to Kilian (2008), this study found, over the entire period, a stronger negative immediate impact and stronger positive corrective effects from supply shocks to GDP (see Figure 7). For speculative shocks, the results found opposite effects to those in Kilian’s (2008) study. The results more closely resembled Melolinna's (2012) results, who analyzed the same period as Kilian using the same method but with a different indicator of aggregate demand (closer to the indicator that was used here) and using a similar sign scheme as was done here. Thus, this suggests that the demand indicator and the approach to the shock identification process used can play an important role in the results produced, especially related to the ‘speculative’ effect.

In this paper, the findings concerning the effects of aggregate demand shocks on GDP (strongly positive immediate impact and strong negative corrective effect) might be partly based on a self-fulfilling prophecy: as real activity - the major indicator for aggregate demand shocks - is typically measured by a business cycle indicator, a shock in aggregate demand largely reflects a business cycle peak. Business cycle peaks logically occur together with increasing GDP, followed by a decline in GDP in the years after the business cycle peak.

Also, the consequence of analyzing the effects over more than three hundred years is that it was necessary to use annual data, while the methodology was initially designed for monthly data. Although a sign-identification method was used to overcome the problem of a biased identification of the different shocks, it is inevitable that the resulting shocks are less ‘pure’ than those identified from monthly data. Also, using the median matrix from the set of admissible shock matrices is not theoretically correct, since the method imposes that every admissible shock matrix is equally likely. It is hoped that the reader will also agree with the authors that the benefits gained from this historical perspective outweigh these limitations.

Altogether, the analysis offers novel findings about the effects of energy price shocks. As current literature only focused on the post-Second World War period and usually only on oil, this paper puts those results in a historical perspective. Indeed, the results indicate that resilience of the British economy to shocks has changed between economic and energy transitions, but has not perceptively improved over the last century. The trend of decreasing shock magnitudes since 1948 has created an illusion of declining vulnerability of the British economy (as shown in Figure 6) but, in fact, may have become more vulnerable in the last one hundred years (as shown in Figure 8). Future research might investigate in more detail the cause of these weaker shocks, and changing vulnerabilities and resiliences associated with the transitions to coal and to oil.

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