A history of aggregate demand and supply shocks for the United Kingdom, 1900 to 2016

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Abstract

This paper presents a history of aggregate demand and supply shocks spanning 1900 – 2016 for the United Kingdom. Sign restrictions derived from a workhorse Keynesian model are used to identify the sign of those shocks. We compare the 30 largest shocks implied by a vector autoregressive model in unemployment and inflation with the narrative historical record. Our approach provides a new perspective on well-known events in economic history. We highlight two episodes of particular interest: an aggregate supply shock in the late 1920s, which we attribute to changes in the bargaining power of labor, and positive aggregate demand shocks in the mid-1970s, which we attribute to fiscal policy.

Keywords: aggregate demand shocks, aggregate supply shocks, sign restrictions, vector autoregressive model, New Keynesian model, economic history.

JEL Codes: C50, C51, N10, N13, N14.

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1 Introduction

Economies are affected by macroeconomic shocks, such as changes in oil prices, financial crises, or international conflicts. These shocks can have a significant impact on lives and livelihoods, and optimal policy responses require knowledge of their underlying nature. The Bank of England, for example, responded to the 2008 financial crisis by implementing a highly expansionary monetary policy. Cover & Mallick (2012) ask, "Is this response reasonable given the types of shocks that are the likely cause of the current slowdown? That is, is the current economic slowdown largely the result of a productivity shock or largely the result of a demand shock?". The answer to this question, and others like it, informs the choice of appropriate policies in response to economic events.

In this paper, we estimate a history of aggregate demand and supply shocks for the British economy, using a vector autoregressive model of unemployment and inflation spanning the years 1900 – 2016. We focus on the 30 largest shocks, comprising 20 demand shocks and 10 supply shocks, for which we provide interpretations based on the narrative historical record. In doing so, we build on an extensive literature studying the macroeconomic history of twentieth century Britain, including Floud & McCloskey (1981, 1994), Broadberry (1986), Capie (1991), and Solomou (1998), as well as recent quantitative studies of British economic history including Thomas et al. (2010), Broadberry et al. (2015), Crafts & Mills (2017), and Dimsdale & Thomas (2019).

Our primary contribution is to identify a history of shocks using sign restrictions derived from the canonical Keynesian aggregate demand / aggregate supply model. Sign restrictions are a common source of identifying information in applied macroeconomics, as they involve considerably weaker assumptions than competing approaches like short-run or long-run point restrictions. In this sense, they are an 'agnostic', or 'minimalist' approach to identification, and are more likely to be agreed upon by a majority of researchers (Uhlig, 2005; Antolín-Díaz & Rubio-Ramírez, 2018). While a number of studies interpret British economic history through the lens of demand and supply shocks (Broadberry, 1986; Solomou, 1998), they often use stronger identification conditions than sign restrictions.

Sign restrictions are, however, subject to criticism. This minimalist approach to identification does not result in point identification, but rather an identified set for objects like economic shocks or impulse response functions, the size of which can make it difficult to draw meaningful conclusions (Lütkepohl & Kilian, 2017). Moreover, commonly used Bayesian priors over the identified set can result in misleading inference (Wolf, 2020). Baumeister & Hamilton (2020) propose a number of solutions to this problem, including the incorporation of additional identifying information, or a strategy for point identification. Their suggestions highlight a fundamental problem: any reduction in the size of the sign-identified set requires extra identifying information, but the use of non-sign information negates the original appeal of sign restrictions (Fry & Pagan, 2011).

The approach employed in this paper only uses the identifying information contained in sign restrictions, and does not require any non-sign information. It is therefore not subject to these criticisms. To achieve this, we exploit a feature of sign restrictions which is rarely utilized in the existing literature: their ability to unambiguously identify the signs of certain structural shocks. Thus, our history pins down the direction of macroeconomic shocks, allowing us to classify them as positive or negative aggregate demand or aggregate supply shocks. As we demonstrate, in conjunction with the narrative historical record, this allows for an economically interesting interpretation of major events such as wars, fiscal expansions and financial crises.

Our findings can be characterized as follows. Overall, we find that aggregate demand shocks are more important than aggregate supply shocks, in the sense that most of the large forecast errors implied by our models are associated with demand shocks. Our shock history supports a number of well-known interpretations of British economic history, including the identification of the two World Wars as positive demand shocks, the identification of the Great Depression and Great Recession as negative demand shocks, and the identification of the 1979 oil price events as a negative supply shock. We provide a detailed interpretation of the entries in our shock history in an appendix, and focus on two episodes of particular interest in the main text. The first is a positive aggregate supply shock in 1927, which we attribute to a sharp reduction in the bargaining power of labor after the general strike of 1926. The second are positive aggregate demand shocks in 1974 and 1975, which we attribute to expansionary fiscal policy by the Heath and Wilson administrations. These examples illustrate the ability of our approach to provide a new perspective on well-known events in economic history.

The existing paper to which our approach is most closely related is Stuart (2019), who presents a history of aggregate demand and aggregate supply shocks for Britain and Ireland spanning 1922 – 1979. Stuart (2019) uses a Keynesian model to identify shocks from a bivariate vector autoregressive (VAR) model in GDP and the price level, relying on the assumption of a unit price elasticity of demand. While the use of workhorse Keynesian macroeconomics to interpret events in economic history is common to our approach, Stuart (2019)'s research question differs as she is interested in examining the dependence of the Irish economy on the British economy, whereas we offer an interpretation of the sources of aggregate shocks in British economic history. Furthermore, Stuart (2019) relies on a point-identification assumption, whereas we impose considerably less identifying information by the use of sign restrictions.

Aside from Stuart (2019), studies that derive series of aggregate demand and supply shocks using VAR models estimated on British historical data include Karras (1993, 1994) and Bergman (1996). Karras (1993) presents a history of demand and supply shocks for the UK, Italy and Sweden between 1868 and 1987 identified via the Blanchard & Quah (1989) restrictions, Karras (1994) applies similar identifying assumptions to the UK, France and Germany between 1960 and 1988, and Bergman (1996) follows the same approach for the UK, Germany, Japan, Sweden and the USA. Liu & Mumtaz (2011), in comparison, present a historical decomposition of the output gap and inflation rate using a fully specified New Keynesian DSGE model.[1] These papers are not, however, chiefly concerned with an interpretation of British economic history, and do not compare their shock histories to the narrative historical record.

Our approach is also related to business cycle accounting (Chari et al., 2007), in the sense that we identify historical shocks using a theoretical model and interpret them based on the narrative historical record. Kersting (2008), for example, studies the 1979–89 economic cycle in Britain using business cycle accounting, and attributes estimated changes in the labor wedge to labor market policies implemented by the Thatcher administration. Chadha & Warren (2013) perform a similar exercise for the 2008–9 recession. The major

[1] After an initial literature search, we searched the set of papers that cited Karras (1993, 1994) or Bergman (1996) for papers that presented *histories* of aggregate demand and supply shocks for the UK. There also exist papers that do this for other countries, e.g., Fackler & McMillin (1998) for the USA. It is also worth noting that a number of papers have examined the applicability of AD-AS models to the UK economy, including Turner (1993), Funke & Hall (1998), Turner (1999), Jenkins & Tsoukis (2000), and Cover & Mallick (2012). However, the focus of these papers is mainly the estimation of impulse response functions.

difference between our approach and business cycle accounting lies again in the strength of the identification restrictions. Our approach can also be compared to the recent work by Jordà (2005) and Jordà et al. (2013, 2015), who apply local projection analysis to a rich historical macroeconomic dataset and document a link between private credit growth and the severity of recessions. While these papers are not concerned with the identification of macroeconomic shocks, sign restrictions can be implemented for impulse response functions estimated by local projection (Plagborg-Møller & Wolf, 2021).

Finally, a number of caveats are in order. First, the validity of statistics identified by sign restrictions is unknown in the presence of measurement error or model misspecification (see Canova & Paustian, 2011, for a discussion of the use of sign restrictions in the presence of model misspecification). We discuss the potential relevance of these limitations in more detail throughout the paper, and also attempt to mitigate their impact through robustness checks, including replacing the unemployment rate series with a gross domestic product series, and selecting large shocks using impulse indicator saturation. These robustness checks support our main results, on the whole, with a notable difference concerning the identification of shocks in the 1970s. Second, we emphasize that while we aim to provide plausible economic interpretations of major shocks, our proposed narrative is by no means the only possible interpretation of these events. Our interpretation is based on major contributions to economic history, but given the scope and richness of this field, other interpretations are certainly possible. We outline the aggregate demand / aggregate supply model in the next section, followed by our identification logic, results, and robustness checks.

2 AD-AS and the New Keynesian model

Despite criticism following the 2008 financial crisis, the workhorse New Keynesian model continues to form the basis of much theoretical and empirical macroeconomics, as well as an important part of economic pedagogy (Fontana & Setterfield, 2009; Galí, 2018). In its reduced form, it boils down to a familiar aggregate demand / aggregate supply (AD-AS) framework that can also be derived from other well-known macroeconomic theories. Its familiarity makes it an ideal starting point to derive the AD-AS model that informs our empirical approach, and it also highlights the importance of the Bank of England's monetary reaction function in shaping the response of the economy to different shocks.

At its heart, the workhorse New Keynesian model is a simple three-equation model, made up of a dynamic IS-curve, a Phillips curve, and a monetary policy rule:

$$y_t = \mathsf{E}_t y_{t+1} - \sigma(i_t - \mathsf{E}_t \pi_{t+1}) + g_t, \tag{IS}$$

$$\pi_t = \beta \mathsf{E}_t \pi_{t+1} + \kappa y_t + \eta_t, \tag{PC}$$

$$i_t = \phi \pi_t + \epsilon_t, \tag{MP}$$

where y_t denotes the output gap (defined as the difference between actual and potential output); π_t denotes inflation; i_t denotes the nominal interest rate; g_t, η_t and ϵ_t are aggregate demand, aggregate supply, and monetary policy shocks, respectively; and σ, β, κ and ϕ are positive parameters. As all the variables are in deviations from their steady state values, we omit intercept terms. We have assumed in (MP) that the central bank is a strict inflation targetter, but incorporating output into the monetary policy rule does not change the relevant results. For a detailed derivation and discussion, see Galí (2008).

A determinate solution to a dynamic stochastic general equilibrium model like the New Keynesian model is one in which the endogenous variables are functions of the pre-determined variables and shock processes. As there are no pre-determined variables in the simple New Keynesian model – e.g., there is no capital stock – a determinate solution is one in which the endogenous variables are functions of the shocks,

$$\begin{bmatrix} y_t \\ \pi_t \\ i_t \end{bmatrix} = B \begin{bmatrix} g_t \\ \eta_t \\ \epsilon_t \end{bmatrix},$$

for some 3×3 matrix B – see e.g., Blanchard & Kahn (1980). As a result, if the shock processes are AR(p), then a determinate solution to the New Keynesian model is a VAR(p) model in which the lag length p is inherited from the shock processes. For example, if g_t, η_t and ϵ_t follow AR(1) processes, then the solution to the New Keynesian model is of the form,

$$z_t = C z_{t-1} + D\xi_t,$$

where $z_t = [y_t, \pi_t]'$, C and D are 2×2 matrices and ξ_t is a 2×1 white noise vector – see e.g., Dennis (2005). Note that in this particular case the interest rate i_t is dropped from the solution, as it is a static variable which can be substituted out.

To understand the sign structure of the responses of output and inflation to the various shocks hitting the economy, consider the simple case in which g_t, η_t and ϵ_t are mean zero white noise. This means that $\mathsf{E}_t g_{t+1} = \mathsf{E}_t \eta_{t+1} = \mathsf{E}_t \epsilon_{t+1} = 0$, and therefore – given the determinate solution form described above – that $\mathsf{E}_t y_{t+1} = \mathsf{E}_t \pi_{t+1} = 0$. Thus, the model with white noise shocks simplifies to,

$$y_t = -\sigma i_t + g_t,$$

$$\pi_t = \kappa y_t + \eta_t,$$

$$i_t = \phi \pi_t + \epsilon_t,$$

which, by substituting out i_t from the IS-curve, yields an AD-AS model,

$$y_t = -\sigma\phi\pi_t + d_t, \tag{AD}$$

$$\pi_t = \kappa y_t + \eta_t, \tag{AS}$$

where $d_t = g_t - \sigma\epsilon_t$ is the aggregate demand shock and η_t is the aggregate supply shock. Note that an increase in d_t is a positive aggregate demand shock, but an increase in η_t is more commonly referred to as a negative aggregate supply shock, as its initial effect is to increase costs (and therefore inflation, ceteris paribus).

In the New Keynesian model, the aggregate demand curve is downward-sloping in (y_t, π_t) space because the central bank raises interest rates when inflation is above its target, and the aggregate supply curve is upward-sloping as firms increase prices when the output gap is positive. It is important to note that $\phi > 0$ is a necessary condition for the first mechanism. While the monetary policy rule might not always fully represent the behaviour of the Bank of England during certain periods, the assumption of $\phi > 0$ is in line with its long-standing commitment to price stability (Capie, 2018). We return to this point when we discuss our results, but it is worth noting at the outset that alternative mechanisms can yield a downward-sloping demand curve in AD-AS models. For example, Dutt & Skott (1996) observe that a downward-sloping demand curve can exist in an economy with a fixed supply of money due to the Keynes effect, or an economy with a fixed interest rate and fixed nominal wages due to the distributional effects of price changes. In general, our sign structure is consistent with the short-run version of the traditional neoclassical synthesis model, and with Post Keynesian models in which inflation is the outcome of distributional conflict (e.g., Hein & Stockhammer, 2010).

With a downward-sloping demand curve and upward-sloping supply curve in (y_t, π_t) space, a positive aggregate demand shock increases output and inflation while a positive aggregate supply shock increases output and decreases inflation. This can also be deduced if we write the solution for output and inflation in terms of the shocks:

$$y_t = \left(\frac{1}{1+\sigma\phi\kappa}\right)(d_t - \sigma\phi\eta_t),$$

$$\pi_t = \left(\frac{1}{1+\sigma\phi\kappa}\right)(\kappa d_t + \eta_t),$$

implying that demand shocks make output and inflation move in the same direction, and supply shocks make output and inflation move in opposite directions.

3 Identifying the signs of demand and supply shocks

In our outline of the New Keynesian model in section 2, we framed the discussion in terms of the deviations of output and inflation from their steady state values. For our main results, we replace output with the unemployment rate, as the output gap is unobservable and – for reasons discussed in more detail below – we expect historical unemployment data to be more reliable than historical estimates of GDP (although we also utilize a GDP series as a robustness check). Consider, therefore, a structural VAR model in the unemployment rate u_t and the inflation rate π_t,

$$Az_t = a + \sum_{i=1}^{p} A_i z_{t-i} + \epsilon_t, \tag{1}$$

in which $z_t = (u_t, \pi_t)'$, and $\epsilon_t = (\epsilon_t^d, \epsilon_t^s)'$ is a mean zero white noise vector process with variance covariance matrix Ω_ϵ. From (1) we have,

$$\mathbb{E}[z_t | z_{t-1}, ..., z_{t-p}] = A^{-1}a + A^{-1}\sum_{i=1}^{p} A_i z_{t-i}, \tag{2}$$

and therefore,

$$z_t - \mathbb{E}[z_t | z_{t-1}, ..., z_{t-p}] = A^{-1}\epsilon_t = v_t, \tag{3}$$

in which $v_t = (v_t^u, v_t^\pi)'$ are the reduced-form innovations, or one-step-ahead forecast errors.

Ordinarily, a VAR practitioner has to make certain assumptions on A and Ω_ϵ to identify the elements of A from the information contained in the variance-covariance matrix of v_t. A popular source of restrictions is the type of sign information derived in section 2, in which AD-AS theory implies that demand shocks make output and inflation move in the same direction, and supply shocks make output and inflation move in opposite directions. Mountford (2005), for example, uses a sign-restricted VAR model to investigate the effects of UK monetary policy, in which positive aggregate supply shocks are assumed to increase output and decrease the price level, and positive aggregate demand shocks are assumed to increase output and increase the price level. However, as discussed by Fry & Pagan (2011) and Lütkepohl & Kilian (2017), sign restrictions only result in set identification, not point identification. In other words, sign restrictions narrow down the set of structural impulse response functions, variance decompositions, and historical decompositions that are consistent with the reduced-form VAR, but do not uniquely identify them. Non-sign information therefore has to be appealed to in order to pin down unique impulse response functions, variance decompositions, and historical decompositions.

Mountford (2005), for example, follows Uhlig (2005) by using a loss function approach to pin down unique 'representative' impulse response functions following set identification by sign restrictions. Essentially, out of the set of impulse response functions which satisfies the sign restrictions, this method chooses the functions which satisfy the sign criteria by the largest margin. The non-sign information appealed to in this example is a loss function, which as the author admits, is arbitrary and does not follow from the theoretical model itself (Mountford, 2005, pp. 602). Fry & Pagan (2011) observe that any solution to the problem of set identification requires the introduction of extra information over and above the information contained in the sign restrictions. Bayesian approaches are the most common way to introduce this non-sign information, but as recently discussed in Wolf (2020), the popular Haar prior over impulse response functions identified using sign restrictions can lead to misleading inference.

Although rarely exploited, there is in fact some unambiguous and economically interesting inference that can be gleaned from sign restrictions without recourse to non-sign information (Calvert Jump, 2018). While much of the VAR literature has focused on the limited use of sign restrictions for identifying impulse response functions, sign restrictions can also be employed to identify the signs of structural shocks. To see this, recall the basic New Keynesian model discussed in section 2, which implies that a positive aggregate demand shock increases output and increases inflation while a positive aggregate supply shock increases output and decreases inflation. Recalling that we have replaced the output gap with the unemployment rate, and assuming that unemployment is negatively related to output, we can impose the following AD-AS sign restrictions on the matrix A in (1) – (3),

$$A = \begin{bmatrix} 1 & -\alpha \\ \beta & 1 \end{bmatrix}, \tag{4}$$

where $\alpha > 0$ and $\beta > 0$, implying that unemployment is increasing in inflation and inflation is decreasing in unemployment. Using (4), we can write (3) as,

$$\begin{bmatrix} u_t \\ \pi_t \end{bmatrix} - \begin{bmatrix} \mathbb{E}[u_t|z_{t-1},...,z_{t-p}] \\ \mathbb{E}[\pi_t|z_{t-1},...,z_{t-p}] \end{bmatrix} = \begin{bmatrix} 1 & \frac{\alpha}{1+\alpha\beta} \\ \frac{-\beta}{1+\alpha\beta} & 1 \end{bmatrix} \begin{bmatrix} \epsilon_t^d \\ \epsilon_t^s \end{bmatrix} = \begin{bmatrix} v_t^u \\ v_t^\pi \end{bmatrix}. \tag{5}$$

Consistent with our discussion of η_t in section 2, we will refer to $\epsilon_t^d < 0$ as a positive demand shock, as this corresponds to a decrease in unemployment, and $\epsilon_t^s < 0$ as a positive supply shock, as this corresponds to a decrease in inflation. Using (5), consider the implications of the four possible combinations of structural shock signs:

1: $\epsilon_t^d < 0,\ \epsilon_t^s < 0 \implies v_t^u = \epsilon_t^d + \frac{\alpha}{1+\alpha\beta}\epsilon_t^s < 0,\ v_t^\pi = \frac{-\beta}{1+\alpha\beta}\epsilon_t^d + \epsilon_t^s \lesseqgtr 0,$

2: $\epsilon_t^d < 0,\ \epsilon_t^s > 0 \implies v_t^u = \epsilon_t^d + \frac{\alpha}{1+\alpha\beta}\epsilon_t^s \lesseqgtr 0,\ v_t^\pi = \frac{-\beta}{1+\alpha\beta}\epsilon_t^d + \epsilon_t^s > 0,$

3: $\epsilon_t^d > 0,\ \epsilon_t^s < 0 \implies v_t^u = \epsilon_t^d + \frac{\alpha}{1+\alpha\beta}\epsilon_t^s \lesseqgtr 0,\ v_t^\pi = \frac{-\beta}{1+\alpha\beta}\epsilon_t^d + \epsilon_t^s < 0,$

4: $\epsilon_t^d > 0,\ \epsilon_t^s > 0 \implies v_t^u = \epsilon_t^d + \frac{\alpha}{1+\alpha\beta}\epsilon_t^s > 0,\ v_t^\pi = \frac{-\beta}{1+\alpha\beta}\epsilon_t^d + \epsilon_t^s \lesseqgtr 0.$

To summarize, a positive demand shock and positive supply shock (case 1) results in a negative unemployment forecast error and an inflation forecast error of unknown sign, and similarly for cases 2 – 4. Working backwards from cases 1 – 4, it is straightforward to deduce the following results:

A: $v_t^u < 0,\ v_t^\pi > 0 \implies \epsilon_t^d < 0,$

B: $v_t^u > 0,\ v_t^\pi < 0 \implies \epsilon_t^d > 0,$

C: $v_t^u > 0,\ v_t^\pi > 0 \implies \epsilon_t^s > 0,$

D: $v_t^u < 0,\ v_t^\pi < 0 \implies \epsilon_t^s < 0.$

To summarize, a negative unemployment forecast error and a positive inflation forecast error (case A) imply the existence of a positive demand shock, and nothing can be said about the sign of the supply shock. A positive unemployment forecast error and a negative inflation forecast error (case B) imply a negative demand shock, and the sign of the supply shock is unknown. A positive unemployment forecast error and a positive inflation forecast error (case C) imply a negative supply shock, and nothing can be said about the sign of the demand shock. Finally, a negative unemployment forecast error and negative inflation forecast error (case D) imply a positive supply shock, and the sign of the demand shock is unknown.

It is also straightforward to infer the results in cases A – D graphically, as illustrated in figure 1. This shows four standard AD-AS diagrams, corresponding to cases 1 – 4 above, with the forecast errors of unemployment and inflation on the horizontal and vertical axes rather than the observed unemployment and inflation rates. As the models considered here are linear, the reader can think of the graphs as showing observed unemployment and inflation rates on the horizontal and vertical axes, respectively, with their expected values at the origin.

Importantly, these results have been arrived at solely with the use of sign restrictions derived from a standard AD-AS model. No non-sign information has been appealed to, and it is also worth noting that no assumptions have been made on the variance-covariance

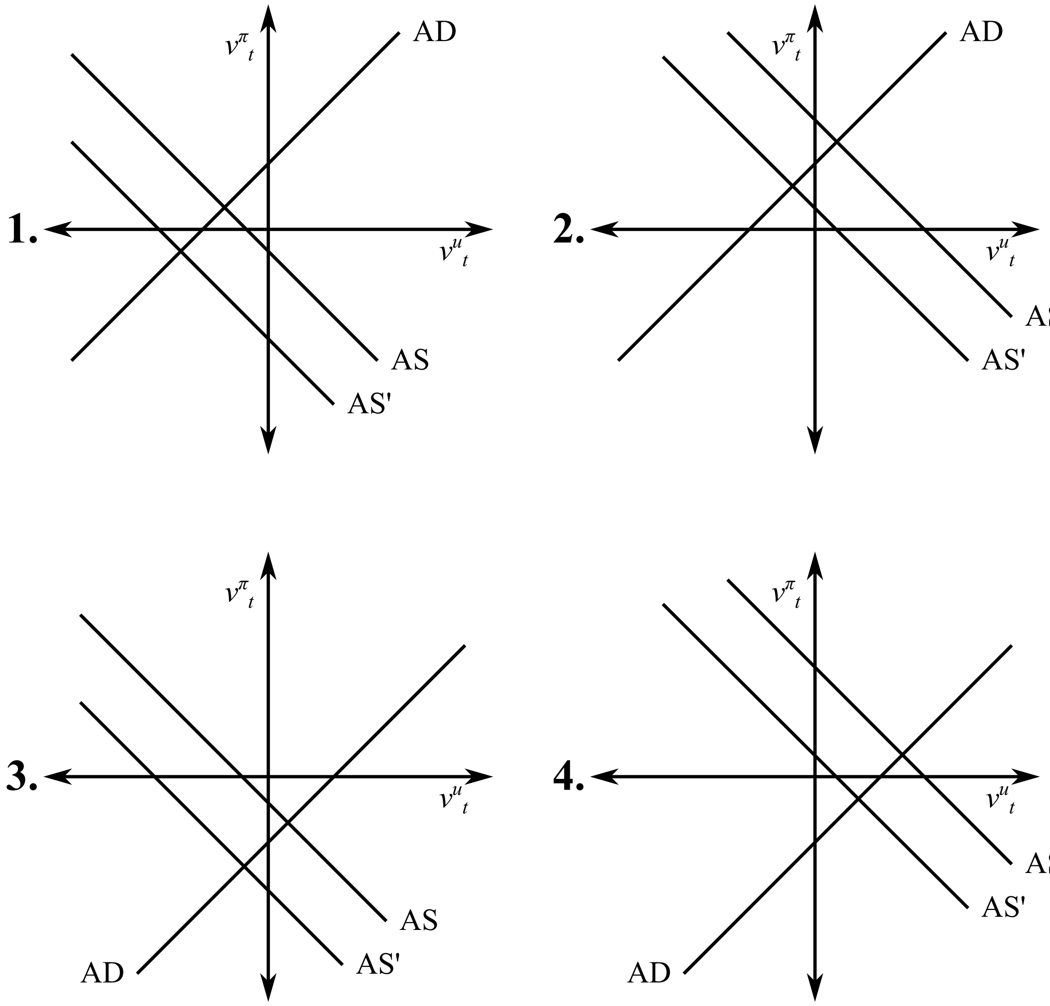

Figure 1: Cases 1 – 4 in section 3. Note the illustrations use differences in the size of the supply shock, but in general the results follow from differences in the relative size of the demand and supply shocks and the magnitudes of α and β.

matrix of the structural shocks – see Cover et al. (2006) or Enders & Hurn (2007) for papers arguing that structural demand and supply shocks in AD-AS models should not be modelled as uncorrelated. Based on this identification strategy, reduced-form residuals $\hat{v}_t^u$ and $\hat{v}_t^\pi$ can be estimated from a VAR to infer the signs of aggregate demand and aggregate supply shocks. We focus on large forecast errors to mitigate inferential problems related to small forecast errors; given our series of VAR forecast errors and identification strategy, we can then interpret the implied structural shock signs using secondary sources from economic history, as recommended by Rudebusch (1998) and Kliem & Kriwoluzky (2013). Finally, it is worth pointing out that we only impose sign restrictions on the contemporaneous matrix of structural parameters, rather than any lagged effects.

4 Data and models

Our main results are based on a reduced-form VAR model in the unemployment and inflation rates, estimated on a sample spanning 1900 – 2016, using the Bank of England's 'millennium

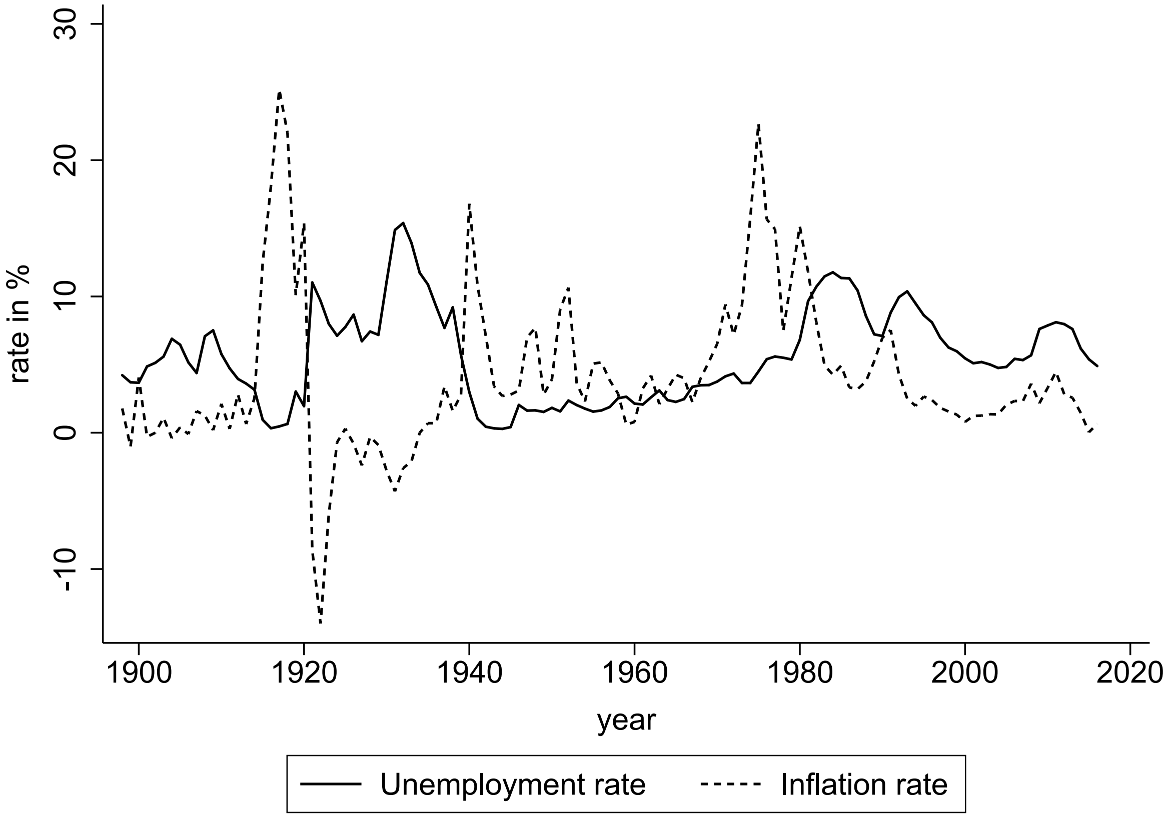

Figure 2: UK unemployment rates and inflation rates, 1900 – 2016.

of macroeconomic data' dataset.[2] This long sample period allows a number of important sources of shocks to be contained within the sample, including the financial turbulence of the 1920s and 1930s, the two World War periods, the high inflation episodes during the 1970s, and the Great Recession of 2009. Figure 2 plots the two series. The rapid inflation during and after the First World War followed by deflation in the 1920s and 1930s are both visible, as is the unemployment peak of 15.4% in 1932. The prolonged period of low unemployment and decreasing inflation following the end of the Second World War is also evident, followed by the rapid increase in inflation during the late 1960s and early 1970s. The sample ends with the relatively high unemployment rates following the early 1980s recession, and the Great Recession following the 2008 financial crisis.

In addition, we also present results using real GDP and the inflation rate, using the same Bank of England dataset.[3] Estimating models using both unemployment and GDP should mitigate, at least in part, concerns we have about measurement error in the pre-War data. In the Bank of England dataset, real GDP estimates are taken from Solomou & Weale (1991) between 1900 and 1913, Sefton & Weale (1995) between 1920 and 1947, and national statistics thereafter, with a 'compromise estimator' used for the First World War and immediate post-war period. As argued by Solomou & Ristuccia (2004), there are significant differences between output, expenditure and income estimates of GDP prior

[2]Specifically, this is the millenniumofdata_v3_final.xlsx sheet, downloaded on 25/08/2017 11.37am from www.bankofengland.co.uk/research/Pages/datasets/default.aspx. The LFS consistent measure of the unemployment rate and the consumer price inflation series are used, both from tab "A1. Headline Series".

[3]We use the natural log of real GDP at market prices.

to the advent of centralized national statistics, and the implied measurement errors are unlikely to be random. As a result, different ways of reconciling the estimates can yield very different GDP figures. Furthermore, as discussed in chapter 5 of Sefton & Weale (1995), the underlying data on which pre-War output, expenditure and income estimates are based are themselves taken from a variety of sources on consumer expenditure, capital formation, wages and salaries, and industrial output. This reflects the absence of modern national accounting in the UK prior to the Second World War.

Unemployment figures, in comparison, are somewhat more straightforward to estimate, but are still likely to suffer from measurement error. The Bank of England dataset uses estimates from Boyer & Hatton (2002) and Feinstein (1972) between 1900 and 1949, and national statistics thereafter. The Boyer & Hatton (2002) and Feinstein (1972) estimates are partly based on trade union unemployment rates, which were also used in official Board of Trade statistics. Boyer & Hatton (2002) extended these figures by using employment data for non-unionized sectors, alongside labor force weights based on the decennial census. Given the conceptual simplicity of employment and unemployment compared to gross domestic product, and the availability of administrative data from trade unions, the Inspectors of Mines, the Board of Trade and others, alongside official statistics from the census, one might expect unemployment to be more accurately measured than GDP. But this is by no means certain, and thus we present results using GDP as a robustness check for our VAR in the unemployment and inflation rates.

The VAR estimates are summarized and discussed in appendix A. Both the VAR in unemployment and inflation, and the VAR in GDP and inflation, use two lags, and we dropped the intercept terms from the unemployment model as they were statistically insignificant at the 5% level, and the inflation equation became slightly more stable when the intercept was excluded. The models do not suffer from autocorrelation at the first lag, but do exhibit heteroskedasticity and non-normality. This is unsurprising given the large shocks obvious in figure 2, but given that the objective of this study is to identify these historical shocks, we do not attempt to correct for it in our baseline results. Instead, we also present models in which large shocks are identified using impulse indicator saturation, as a robustness check. As the residuals are highly non-normal, RESET tests for omitted non-linearities were applied equation-by-equation for the unemployment model, but no evidence of non-linearity was found. Despite the sample being relatively long, the estimates are remarkably stable, as illustrated by the CUSUM plots of the cumulative sum of the recursive residuals, as well as recursive parameter estimate plots.

The model in the unemployment and inflation rates has two real eigenvalues equal to 0.98 and 0.74, and two complex conjugate eigenvalues equal to $0.17 \pm 0.21i$. The eigenvalue equal to 0.98 suggests a unit root process, providing further support to our exclusion of the intercepts from the final model, given that neither series has an obvious drift that would be captured by an intercept term. The complex conjugate eigenvalues imply a business cycle component with an average period of approximately 7 years, although from figure 2 it is obvious that the business cycle component does not account for a large part of the variance of unemployment and inflation in the UK.[4] Instead, there are clearly large shocks impacting unemployment and inflation. These shocks lead to the reduced-form residuals plotted in figure 3, from which the considerable forecast errors during the war periods and 1920s are immediately apparent. Large inflation forecast errors are also apparent in the late 1940s and early 1950s, and the late 1970s and early 1980s. Large unemployment forecast errors

[4] A pair of complex conjugate eigenvalues $\lambda = a \pm bi$ imply a sinusoidal component of period $2\pi/\arctan(b/a)$, which in this case is $2\pi/\arctan(0.21/0.17) = 7.058$. See Shibayama (2008) for details.

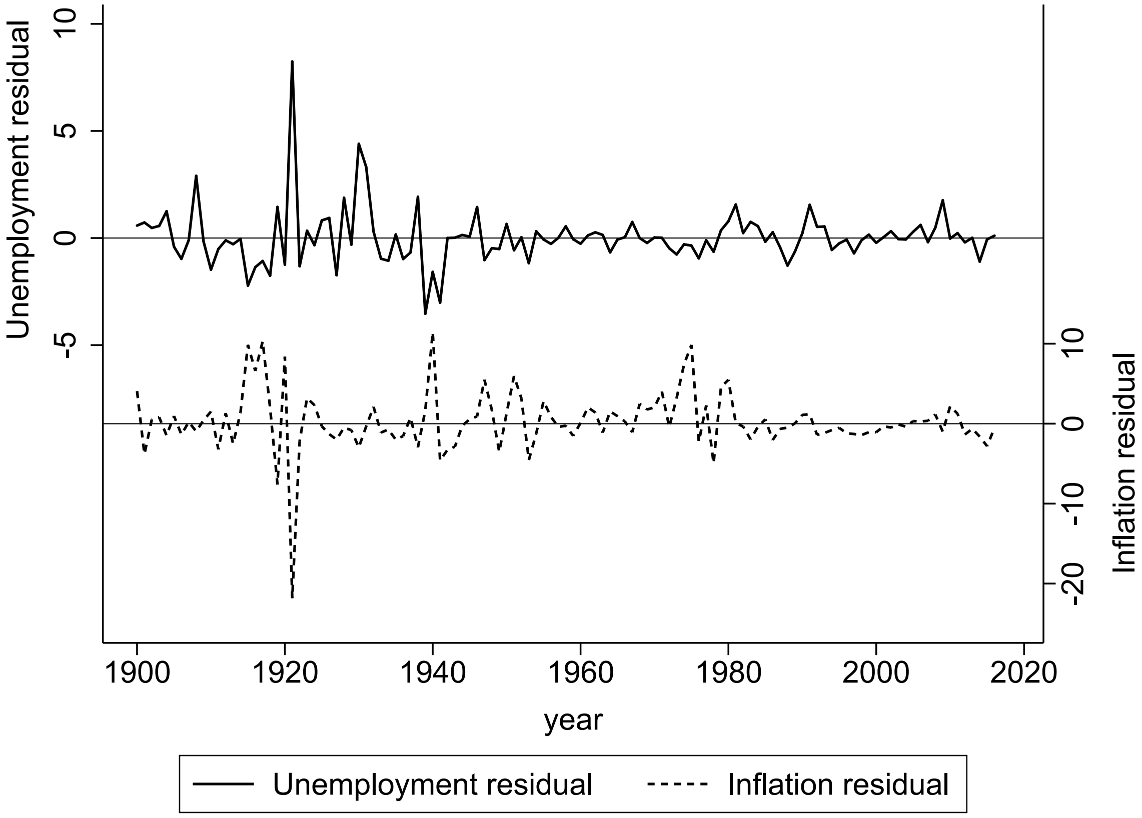

Figure 3: VAR residuals, 1900 – 2016. Details of the VAR can be found in appendix A.

are visible around the recessions of the early 1980s, early 1990s, and late 2000s. Using the method outlined in section 3, these forecast errors are used to derive a history of aggregate demand and supply shocks in the next section.

5 A history of aggregate demand and supply shocks

5.1 Main results

Table 1 presents a history of aggregate demand and supply shocks implied by the identification strategy outlined in section 3, using the VAR model in unemployment and inflation discussed in section 4. We include the thirty largest shocks in table 1, which are chosen by ranking years based on their largest normalized residual by absolute value. As there are 117 years in the sample, this means that table 1 includes the largest 25% of shocks in the sample, approximately. To aid the reader, we include the normalized residuals in the table. For example, both the unemployment and inflation residuals for 1915 are greater than their respective standard deviations, in absolute value. As the unemployment residual is negative and the inflation residual positive, the identification strategy outlined in section 3 suggests that there was an aggregate demand shock in 1915. We provide a detailed discussion of the majority of the shocks in appendix B, and summarize our reasoning in the 'interpretation' column of table 1.

We first note that our interpretation of some of the most well-known events in British economic history is in line with common interpretations. The World Wars between 1914 –

Table 1: Implied demand and supply shocks, VAR with unemployment and inflation

Date	$\hat{v}^{u}_{n,t}$	$\hat{v}^{\pi}_{n,t}$	Implied demand shock	Implied supply shock	Interpretation
1900	0.45	1.09		$-$	Commodity prices
1908	2.24	-0.26	$-$		1907 financial crisis
1910	-1.14	0.41	$+$		People's Budget
1915	-1.71	2.65	$+$		First World War
1916	-1.05	1.78	$+$		First World War
1917	-0.82	2.77	$+$		First World War
1918	-1.36	0.53	$+$		First World War
1919	1.12	-2.05	$-$		Fiscal retrenchment
1920	-0.96	2.26	$+$		Global post-war boom
1921	6.36	-5.87	$-$		Gold standard
1927	-1.34	-0.53		$+$	Bargaining power
1928	1.45	-0.13	$-$		*Unknown*
1930	3.39	-0.80	$-$		Great Depression
1931	2.56	-0.09	$-$		Great Depression
1938	1.49	-0.79	$-$		Recession in USA
1939	-2.73	0.44	$+$		Second World War
1940	-1.22	3.08	$+$		Second World War
1941	-2.33	-1.24		$+$	*Unknown*
1946	1.12	0.24		$-$	*Unknown*
1947	-0.80	1.48	$+$		*Unknown*
1951	-0.44	1.60	$+$		Korean War
1953	-0.90	-1.23		$+$	*Unknown*
1974	-0.23	1.99	$+$		Fiscal expansion
1975	-0.27	2.65	$+$		Fiscal expansion
1978	-0.49	-1.34		$+$	Social contract
1979	0.28	1.23		$-$	Oil prices
1980	0.60	1.47		$-$	Oil prices
1981	1.21	0.02		$-$	Oil prices
1991	1.20	0.32		$-$	Oil prices
2009	1.36	-0.27	$-$		2008 financial crisis

Notes: Unemployment and inflation residuals normalized by their respective sample standard deviations are denoted by $\hat{v}^{u}_{n,t}$ and $\hat{v}^{\pi}_{n,t}$, respectively. Years are ranked by $\max(\text{abs}(\hat{v}^{u}_{n,t}), \text{abs}(\hat{v}^{\pi}_{n,t}))$, and the 30 highest ranked years are included in the table. In columns 4 and 5, $+$ denotes a positive shock and $-$ denotes a negative shock. World War years are highlighted in grey. Details of the VAR model can be found in appendix A.

1918 and 1939 – 1945 are associated with positive demand shocks, whereas negative demand shocks are present during the Great Depression in 1930 and 1931 and the Great Recession in 2009. Negative supply shocks are present following the 1979 oil price shock. Second, we find that there are considerably more large aggregate demand shocks than large aggregate supply shocks, so on this measure demand shocks were more important than supply shocks for the evolution of UK unemployment and inflation between 1900 and 2016. However, we also note that large supply shocks are more prevalent than large demand shocks after 1970, which is consistent with the results that Liu & Mumtaz (2011) arrive at using a DSGE model, in which aggregate supply shocks are relatively important for output fluctuations using a sample that starts in 1970.

As well as yielding further support for existing interpretations of British economic history, our results also provide a new perspective on well-known events. For example, a particularly interesting entry in table 1 is the positive supply shock in 1927. According to an influential interpretation of the inter-war British economy, there were no supply shocks of any importance in the late 1920s:

> "One clear result ... is that supply factors were only important during the early 1920s. There were no further supply shocks during the later 1920s or the 1930s, when fluctuations were due to demand shocks." (Broadberry, 1986, pp. 14).

However, our estimates indicate the existence of a positive aggregate supply shock in 1927, associated with a relatively large reduction in the unemployment rate. As with all of the shocks in table 1, there are many possible explanations that could be consistent with the evidence. Bearing this in mind, we suggest that the supply shock in 1927 can be attributed to a sudden fall in the bargaining power of labor following the 1926 general strike, which took place over nine days at the beginning of May 1926, and followed a long period of failed negotiations over miners' wages (which had fallen significantly since the end of the First World War). After the failure of the strike, the Trade Disputes and Trade Unions Act (1927) and the Unemployment Insurance Act (1927) were passed. Unions were prevented from acting in a 'political' manner, secondary strike action was made illegal, and,

> "What followed was a systematic campaign to tighten up the existing administration of unemployment insurance. The 'seeking work' test, of course, had already made its mark. By 1927 one in ten of all claimants was being refused benefit because of an 'unsatisfactory attitude to work'." (Garside, 1990, pp. 48).

These restrictions on trade union activity, and the tightening of unemployment insurance, were associated with a fall in the number of working days lost to strikes from 162.2 million in 1926 to just 1.2 million in 1927 – lower than any year since the 1890s. As illustrated in figure 4, the sharp increase in strike days in 1926 and subsequent collapse in 1927 were a mirror image of changes in labor productivity growth in the same years. In fact, labor productivity growth and strike activity were negatively correlated in the 1920s, with a simple linear regression suggesting that an increase in strike days of 33 million was associated with a one percentage point decline in productivity growth during this decade. Allowing for the inductive nature of this argument, and the possibility of alternative explanations, we therefore interpret the source of our supply shock in 1927 as a reduction in bargaining power.

5.2 Results from a VAR in GDP and inflation

In this section, we present two robustness checks on our results, given that little is known about the validity of sign restrictions in the presence of measurement error or model mis-

Figure 4: Working days lost to strikes (left axis) and labor productivity growth (right axis) between 1920 and 1930. Labor productivity data (in heads) taken from the Bank of England dataset; strike days taken from the ONS Labour Disputes bulletins.

specification. The first of these replaces the unemployment series with log real GDP (see table 2). We note that 17 out of the 30 shocks are in agreement with the shocks identified in table 1, 7 are in disagreement, and 6 are in years that do not appear in table 1.

Interestingly, pre-War measurement error does not seem to be particularly important, in the sense that the GDP model is just as likely to disagree with the unemployment model before 1945 as after 1945. In fact, two out of the three pre-1945 years in which the GDP model disagrees with the unemployment model are during the First World War, for which there are no reliable GDP data. Notably, our 1927 supply shock does appear in table 2, suggesting that this event is not due to measurement error in the unemployment series. Instead, the decade with sustained differences in shock identification is the 1970s. Specifically, the unemployment model identifies positive demand shocks in 1974 and 1975, and a negative aggregate supply shock in 1979, while the GDP model identifies negative aggregate supply shocks in 1974 and 1975, and a positive aggregate demand shock in 1979.

The 1970s are, therefore, an interesting example of the limits of our approach. If we consider the case of 1974 and 1975, a 'textbook' interpretation would associate the late 1973 to early 1974 oil price increases as a negative aggregate supply shock related to the Yom Kippur War (e.g. Blanchard, 2017, pp. 207-208). The interpretation of the mid-1970s as a period of oil price shocks is also offered in Hendry (2001), who finds that foreign prices were a major driver of UK price inflation in 1974 and in 1975. At the same time, it is also commonplace in the economic history literature to note the unusually expansionary nature

Table 2: Implied demand and supply shocks, VAR with GDP and inflation

Date	$\hat{v}^{gdp}_{n,t}$	$\hat{v}^{\pi}_{n,t}$	Implied demand shock	Implied supply shock	Match with table 1
1908	-2.29	-0.33	−		✓
1915	1.27	2.57	+		✓
1916	-0.27	1.64		−	✗
1917	-0.14	2.86		−	✗
1918	1.27	0.65	+		✓
1919	-2.93	-1.94	−		✓
1920	-1.34	2.90		−	✗
1921	-2.85	-5.25	−		✓
1922	2.20	-0.92		+	✓
1926	-2.14	-0.71	−		*Not in table 1*
1927	2.55	-0.35		+	✓
1928	-1.31	-0.28	−		✓
1930	-1.26	-0.92	−		✓
1931	-2.31	-0.63	−		✓
1940	2.44	3.52	+		✓
1941	1.99	-1.63		+	✓
1944	-2.36	-0.15	−		*Not in table 1*
1945	-1.62	0.46		−	*Not in table 1*
1947	-0.61	1.34		−	✗
1951	0.49	1.26	+		✓
1953	1.60	-1.47		+	✓
1973	1.36	0.67	+		*Not in table 1*
1974	-2.04	1.72		−	✗
1975	-0.23	2.94		−	✗
1976	1.53	-0.49		+	*Not in table 1*
1978	1.10	-1.31		+	✓
1979	0.36	1.28	+		✗
1980	-1.45	1.33		−	✓
2008	-1.23	0.19		−	*Not in table 1*
2009	-2.15	-0.24	−		✓

Notes: Log GDP and inflation residuals normalized by their respective sample standard deviations are denoted by $\hat{v}^{gdp}_{n,t}$ and $\hat{v}^{\pi}_{n,t}$, respectively. Years are ranked by $\max(\text{abs}(\hat{v}^{gdp}_{n,t}), \text{abs}(\hat{v}^{\pi}_{n,t}))$, and the 30 highest ranked years are included in the table. In columns 4 and 5, + denotes a positive shock and − denotes a negative shock. In column 6, ✓ denotes a match with table 1 and ✗ denotes a mismatch. World War years are highlighted in grey. Details of the VAR model can be found in appendix A.

of British fiscal policy during the mid-1970s. Jim Tomlinson, for example, has observed that,

> "In the 1972–4 period the Conservative government under Heath ... pursued expansionary macro-economic policies to increase growth and reduce unemployment. The succeeding Labour government initially did the same, even in the face of the deflationary effects of the OPEC price rise of 1973/4. But by 1975/6 the rise in inflation and fall in the value of the pound led to a reversal of priorities, often seen as epochal." (Tomlinson, 1994, pp. 260).

While the negative supply shocks found with GDP lend support to the oil-shock narrative, the positive aggregate demand shocks found with the unemployment rate are consistent with an effect of expansionary fiscal policy. Indeed, a 250% increase in the public sector borrowing requirement between 1974 and 1976 followed the Barber boom earlier in the decade (Tomlinson, 1985, pp. 130).

It is, of course, possible that there were both large demand and supply shocks in the mid-1970s. Rebecca Stuart, using more restrictive identification conditions than us (and data on GDP, rather than unemployment), finds that,

> "The first oil crisis in 1973 is marked by a severe negative aggregate supply shock in 1974. Nonetheless, the new Labour government's spending policies are marked by a positive aggregate demand shock in the same year." (Stuart, 2019, pp. 628).

In fact, there is evidence that the Chancellor at the time, Denis Healey, consciously adopted a reflationary fiscal policy in response to the oil price crisis, knowing that it would prevent further increases in unemployment at the risk of exacerbating inflation. In November 1974, for example, Healey stated in the Commons,

> "Yet there is no real evidence that in this situation the adoption of deflationary policies will produce a worthwhile impact on the rate of inflation – at any rate within a time scale that democracy will tolerate." (quoted in Tomlinson, 1985, pp. 171).

He went on to argue that, despite Britain being badly affected by the oil crisis, "to adopt a strategy which requires mass unemployment would be no less an economic than a moral crime." (Hansard, 1974).

On the other hand, the disagreements between tables 1 and 2 in the 1970s could be due to model misspecification. As discussed in section 2, one important determinant of a downward-sloping aggregate demand curve, and thus the validity of our identification restrictions, is a monetary policy rule that responds positively to inflation. As discussed by Goodhart (1989), Nelson (2003) and others, the 1970s was a decade of structural changes in monetary policy, with the end of fixed exchange rates and the temporary pursuit of monetary targets in the late 1970s. Indeed, Goodhart (2018, p.153) describes the years 1972–77 as, "confused, and disturbed", and it is possible that one or both of our unemployment and GDP models might be providing misleading inference during this period. Even if there existed other, non-policy mechanisms ensuring a downward-sloping demand curve in the 1970s (as outlined in section 3), there still might be localized parameter instability during this decade caused by changes in the conduct of monetary policy.

In any case, economic events in the 1970s were unusually turbulent and prompted unconventional fiscal and monetary policy interventions that are likely to have affected both the demand and supply sides of the British economy. The policies followed by the Wilson government, including incomes policies to control inflation, were, "full of forecasting problems and uncertainty over theoretical and empirical relationships." (Artis et al., 1992, pp. 42). While the results in tables 1 and 2 do not suggest that pre-War measurement error is a serious impediment to inference, therefore, they do suggest that a closer examination of the 1970s might be a worthwhile pursuit.

5.3 Results using impulse indicator saturation

In this section we present the results of our second robustness check, which compares our baseline approach to impulse indicator saturation (IIS) as an alternative method of dealing with shocks in macroeconomic time series. IIS is a form of general-to-specific modelling which is a data-driven approach that involves starting from a general unrestricted model that encompasses multiple explanatory variables as well as a set of dummy variables to capture idiosyncratic events such as wars, natural disasters, policy regime shifts and so forth. IIS provides a selection algorithm that helps identify dummy variables that absorb those shocks. Santos et al. (2007) and Castle & Hendry (2014) discuss the statistical properties of IIS, and Castle & Hendry (2009), Hendry & Mizon (2011) and Castle et al. (2012) present empirical applications.

More specifically, IIS selects relevant impulse indicators, i.e., dummy variables that are unity in a specific period and zero otherwise, which absorb shocks that are not captured by the explanatory variables. In the split-half approach, a subset of size $T/2$ from a full set of impulse indicators denoted by I_t, $t = 1, .., T$, is included in the regression equation along with the observable variables, which is then estimated on the T observations. By only using the first half of the T impulse indicators, it is ensured that there are enough degrees of freedom to estimate the parameters of the equation. In the next step, the second half of the impulse indicators is included. Finally, only those indicators that are statistically significant at a predetermined level are retained to arrive at the desired model. As discussed in Castle & Hendry (2014), these indicators capture location shifts in the time series, meaning that the shocks isolated using this method can be understood as a type of structural break.[5]

To compare our baseline approach with IIS, we re-estimate the VAR in unemployment and inflation using IIS to select a set of statistically significant impulse dummies. IIS has so far mostly been used in a single-equation context. In order to apply it to our bivariate VAR, we simply retain indicators whenever they are statistically significant in either one or both of the two equations. The structural VAR model augmented with impulse indicators is,

$$Az_t = a + \sum_{i=1}^{p} A_i z_{t-i} + \beta_t I_t + \epsilon_t, \tag{6}$$

and the forecasts errors augmented by the impulse indicators are,

$$z_t - \mathbb{E}[z_t|z_{t-1}, ..., z_{t-p}] = A^{-1}\beta_t I_t + A^{-1}\epsilon_t = b_t I_t + v_t, \tag{7}$$

where $v_t = (v_t^u, v_t^\pi)'$ are the reduced form innovations, I_t are the impulse indicators selected by IIS, and $A^{-1}\beta_t = b_t = (b_t^u, b_t^\pi)'$ are the reduced-form parameters on the impulse indicators.

[5] Other methods to estimate unknown structural breaks in time series include those of Andrews (1993) and Bai & Perron (2003), which we do not utilize but could be an interesting avenue for future research.

Table 3: Implied demand and supply shocks, impulse indicator saturation

Date	$\hat{b}_t^u$	$\hat{b}_t^\pi$	Implied demand shock	Implied supply shock	Match with table 1
1900	0.56	3.36		−	✓
1901	0.68	-4.23	−		*Not in table 1*
1904	1.17	-1.95	−		*Not in table 1*
1908	2.98	-1.24	−		✓
1910	-1.51	1.29	+		✓
1911	-0.25	-2.93		+	*Not in table 1*
1913	-0.22	-2.78		+	*Not in table 1*
1915	-2.24	9.35	+		✓
1916	-1.11	7.02	+		✓
1917	-1.08	10.51	+		✓
1918	-1.85	2.50	+		✓
1919	1.31	-7.40	−		✓
1920	-1.72	7.44	+		✓
1921	8.34	-21.41	−		✓
1922	-2.66	-5.19		+	*Not in table 1*
1923	0.585	2.79		−	*Not in table 1*
1927	-1.80	-2.21		+	✓
1928	2.18	-0.35	−		✓
1930	4.46	-3.13	−		✓
1931	2.86	-1.19	−		✓
1938	2.23	-2.30	−		✓
1939	-3.67	1.50	+		✓
1940	-1.05	12.28	+		✓
1941	-2.60	-3.35		+	✓
1942	0.14	-3.20	−		*Not in table 1*
1943	-0.07	-3.55		+	*Not in table 1*
1946	1.25	-0.25	−		✗
1947	-1.40	4.21	+		✓
1949	-0.63	-4.08		+	*Not in table 1*
1951	-0.74	5.09	+		✓
1953	-1.37	-4.99		+	✓
1974	-0.23	7.54	+		✓
1975	-0.36	10.28	+		✓
1980	0.83	5.91		−	✓

Notes: Indicators were selected using a 5% significance level. In column 6, ✓ denotes a match with table 1 and ✗ denotes a mismatch. The identification of shocks is based on the method discussed in section 3 and does not follow from IIS.

Comparison of (7) with (3) shows that the large shocks will be captured by $b_t I_t$, with the estimated parameters $\hat{b}_t = (\hat{b}_t^u, \hat{b}_t^\pi)'$ replacing the estimated residuals $\hat{v}_t = (\hat{v}_t^u, \hat{v}_t^\pi)'$ in the periods in which indicators are selected. As a result, we can interpret the IIS results in the same way that we interpret large forecast errors, with $\hat{v}_t$ replaced with $\hat{b}_t$.

Table 3 summarizes the main results, in which the impulse indicators are selected using a significance level of 5%; the full results are reported in Appendix C. The table includes the date of each selected impulse indicator, the reduced-form parameter estimates on the indicator for each equation, and the signs of the implied aggregate demand or supply shock identified using the theory-based sign restrictions discussed above. In addition, the sixth column indicates whether the implied demand or supply shock is consistent with the implied shock in table 1. With a 5% significance level, 34 impulse indicators are retained, of which 24 match the corresponding shocks in table 1, 9 are not included in table 1, and only one shock is inconsistent with the corresponding shock in table 1.[6] This is the 1946 shock, which is identified as a negative supply shock in table 1 and a negative demand shock in table 3, for which – as discussed in appendix B – there is no obvious explanation. Overall, therefore, there is a strong correspondence with the shocks identified in section 5.1. This exercise shows that the history of significant shocks presented in section 5 is robust to the method used to identify large forecast errors.

6 Concluding remarks

In this paper, we have presented an interpretation of the history of aggregate demand and supply shocks in the United Kingdom from a Keynesian perspective. To achieve this, we have utilized a rarely exploited feature of sign restrictions, which allows the signs of certain structural shocks to be derived from the reduced-form residuals of a VAR model using minimal identification assumptions. This contribution is inspired by Charles Manski's approach to partial identification:

> "Social scientists and policymakers alike seem driven to draw sharp conclusions, even when these can be generated only by imposing much stronger assumptions than can be defended. We need to develop a greater tolerance for ambiguity. We must face up to the fact that we cannot answer all of the questions that we ask." (Manski, 1995, pp. 7-8).

Importantly, our approach is not subject to the criticism that sign restrictions only provide information of limited economic use, and therefore need to be augmented by additional identifying information (Fry & Pagan, 2011; Antolín-Díaz & Rubio-Ramírez, 2018; Baumeister & Hamilton, 2020). Despite utilizing only weak restrictions implied by a Keynesian aggregate demand/aggregate supply model, we were able to document a number of interesting findings about UK macroeconomic history.

Our results include the identification of World War years as positive aggregate demand shocks, the Great Depression and Great Recession as negative aggregate demand shocks, and the identification of the 1979 oil price events as a negative aggregate supply shock. Overall, we find a greater role for aggregate demand shocks, rather than aggregate supply shocks, in British macroeconomic history. We also uncover some interesting events which are less well-known, including a positive aggregate supply shock in 1927, which coincides with

[6] With a statistical significance level of 10%, 45 indicators are retained, and with a 1% level only 16 indicators are retained, see Appendix C.

labor market reforms in the aftermath of the 1926 General Strike. The decade in which our results are more ambiguous is the 1970s, which might be due to measurement error, model misspecification, or the unusually complex external and policy-making environment in that decade. Our results are consistent with both negative supply shocks in 1974 and 1975 related to the oil crisis and positive demand shocks that may stem from expansionary fiscal policy. After 1979, our history is more familiar, being dominated by negative aggregate supply shocks until the Great Recession in 2009, which is the last major shock we identify.

While previous research on historical macroeconomic shocks has often relied on relatively strong theoretical assumptions to achieve identification (e.g. Bergman 1996; Karras 1993, 1994; Liu & Mumtaz 2011; Stuart 2019), we show that sign restrictions can provide economically interesting information with much weaker assumptions. Our approach could easily be applied to other countries, particularly those with long historical time series. At the same time, in order to further explore the applicability of the AD-AS model to the UK, it may be worth applying other identification methods such as identification by heteroskedasticity or non-normality. As far as we are aware, neither of these methods have been applied to historical UK time series data, and the results reported in this paper suggest that they may well be useful. Finally, an interesting extension would use more series to split up our demand and supply shocks into less aggregated shocks – for example, by using asset price data to separate financial and non-financial demand shocks, as in Nolan & Thoenissen (2009). We leave these avenues to future research.

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Appendices

A Stability plots

The VAR estimates for the unemployment model are summarized in table A1. Unit root tests are inconclusive, although there is no obvious drift in either the unemployment or inflation series. The Akaike information criterion indicates a two lag model. The intercept terms were dropped in the final estimations because they were statistically insignificant at the 5% level, and the inflation equation became slightly more stable when the intercept was excluded. Intuitively, if both unemployment and inflation follow a unit root process with no drift, then the intercept estimator is $\sqrt{T}$-consistent, so converges at a slower rate than the T-consistent slope estimator. Including intercepts appears to increase parameter instability in our VAR estimates, and therefore they are excluded. However, the residual series from the VARs estimated with and without intercepts are almost identical; see the scatter matrix and kernel densities in figure D2 in appendix D.

The models appear to exhibit heteroskedasticity and non-normality. This is unsurprising given the large shocks obvious in figure 2, but given that the objective of this study is to identify these historical shocks, we do not attempt to correct for it. As the residuals are highly non-normal, RESET tests for omitted non-linearities were applied equation-by-equation, but no evidence of non-linearity was found. Despite the sample being long, the estimates are remarkably stable, as illustrated by the CUSUM plots of the cumulative sum of the recursive residuals, as well as the recursive parameter estimate plots. The CUSUM plot for the inflation equation in figure A2 can be compared to its equivalent from a VAR estimated with intercepts in figure D1, for evidence that the estimates excluding intercepts are slightly more stable. The estimates for the GDP model are summarized in table A2.

Table A1: VAR regression output, unemployment model

	u_t	π_t
u_{t-1}	1.275	-0.629
	(12.46)	(-2.14)
u_{t-2}	-0.318	0.728
	(-3.14)	(2.51)
π_{t-1}	0.135	0.779
	(3.78)	(7.56)
π_{t-2}	-0.0827	0.0258
	(-2.21)	(0.24)
N	117	

t statistics in parentheses

The p-value from an LM test for autocorrelation on the first lag is 0.098

The p-value from a Jarque-Bera test is zero

Table A2: VAR regression output, GDP model

	$\ln y_t$	π_t
$\ln y_{t-1}$	1.362	29.12
	(15.52)	(2.48)
$\ln y_{t-2}$	-0.359	-29.14
	(-4.07)	(-2.46)
π_{t-1}	-0.00128	0.818
	(-1.89)	(9.03)
π_{t-2}	0.000187	-0.0723
	(0.27)	(-0.77)
intercept	-0.0211	0.711
	(-0.47)	(0.12)
N	117	

y_t denotes real GDP at market prices; t statistics in parentheses

The p-value from an LM test for autocorrelation on the first lag is 0.067

The p-value from a Jarque-Bera test is zero

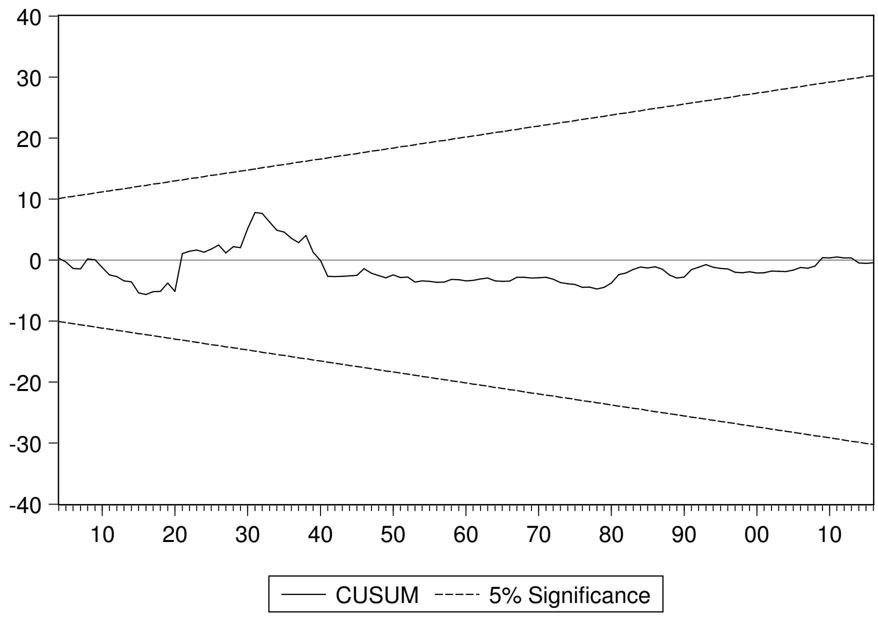

Figure A1: CUSUM test output, unemployment equation.

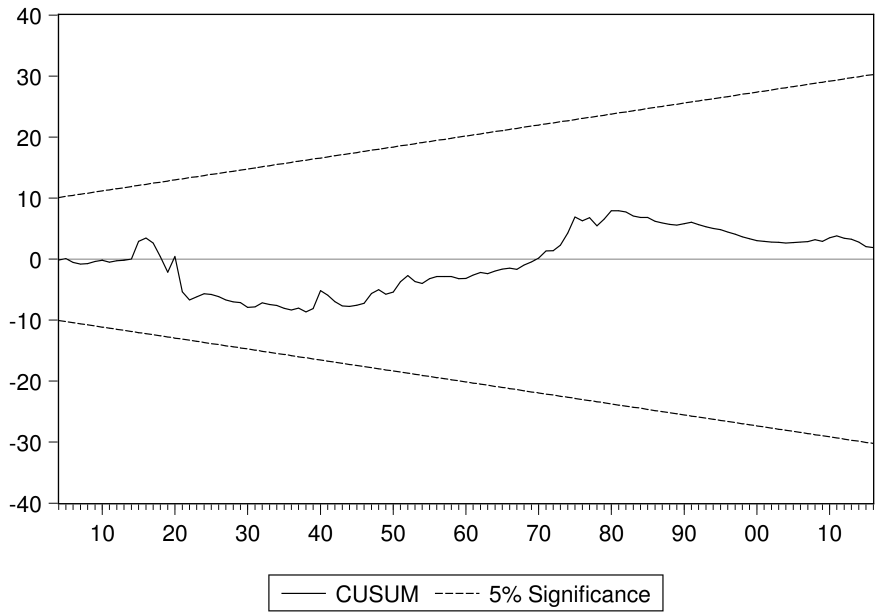

Figure A2: CUSUM test output, inflation equation.

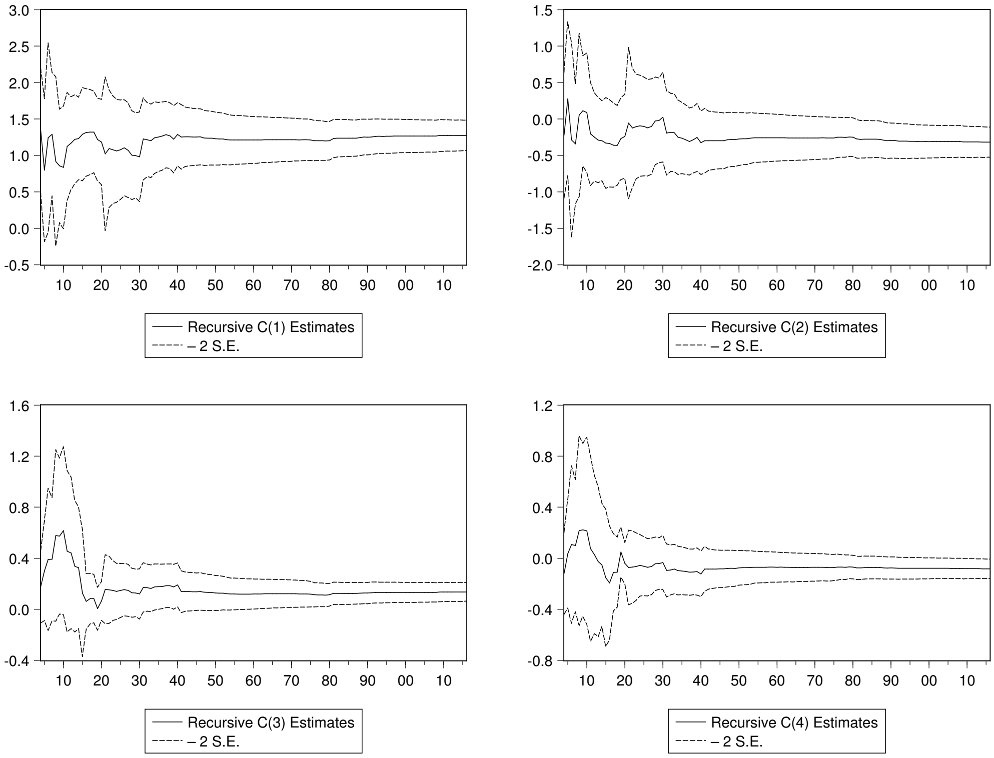

Figure A3: Recursive parameter estimates, unemployment equation.

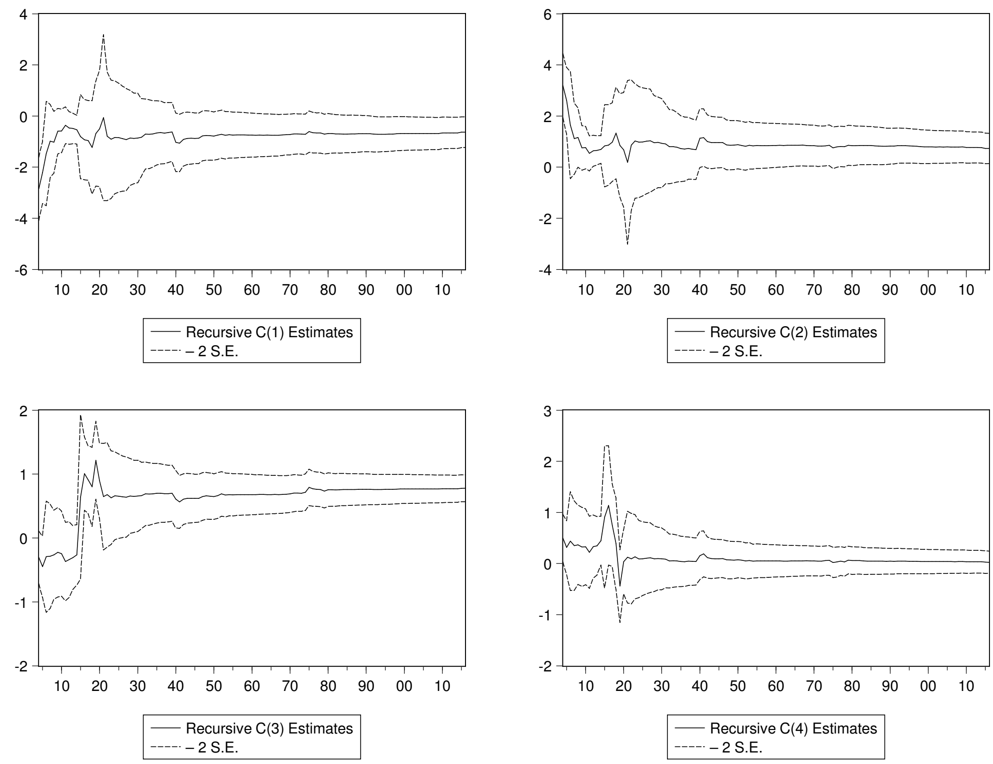

Figure A4: Recursive parameter estimates, inflation equation.

B Detailed discussion of shocks in table 1

B.1 1900

Willard Long Thorp, in an exhaustive narrative account of business cycle conditions from 1790 to 1925, describes 1900 as a prosperous year, leading to recession in the Summer, with,

> "Activity and progress, first half-year, yield to dullness and decline, summer; gradual increase in unemployment; commodity prices reach peak and then decline; coal prices extremely high; big increase in volume of foreign trade, slackening later in year . . . Money tight, with large government loans floated; stock market unsteady with rapid rise in industrial stocks, first quarter, and boom in American railways . . . Smaller crops, except oats; higher prices . . . War continued with increasing demands for men and materials; British successes begin, March." (Thorp, 1926, pp. 173).

The war that Thorp refers to is the Boer War, which was declared the preceding year. The high commodities prices, with higher crop prices due to a poor harvest, may be taken as the source of the negative supply shock in table 1.

B.2 1908

The negative aggregate demand shock in 1908 listed in table 1 can easily be explained by the 1907 financial crisis in the USA, which took place in October and the beginning of November of that year. This was the high point of pre-war globalization, and as pointed out in Thomas et al. (2010),

> "The UK business cycle became more closely aligned with external factors as international linkages became more important following the widespread adoption of the gold standard system of fixed exchange rates. Consequently . . . the UK economy was vulnerable to international financial crises, such as the 1907 US financial crisis." (Thomas et al., 2010).

Willard Long Thorp, in his account of business cycle conditions, describes 1908 as a depression, with,

> "Marked and rapid decline in all branches of industry; stagnation; severe unemployment reaches peak, autumn; many wage reductions; severe engineering strike, summer, and general lockout in Lancashire cotton industry, autumn; many failures; large reduction in volume of foreign trade." (Thorp, 1926, pp. 175).

Thus, sharp reduction in foreign trade, driven in the main by the 1907 financial crisis, marks this period out as suffering from a severe negative aggregate demand shock, although the "dull" stock exchange and declining stock prices also point to a degree of financial contagion from the crisis (Thorp, 1926, pp. 175).

B.3 1910

Unemployment, having risen to 7.08% in 1908 and 7.51% in 1909, fell back to 5.77% in 1910 during the recovery from the previous recession. Inflation rose from 0.19% to 2.12%

from 1909 to 1910, leading to the positive aggregate demand shock listed in table 1. This period is, of course, before any attempts at active demand management by the Government, and the Bank Rate was steady at 4.5% between 1909 and 1910. However, 1910 did see the passage of Lloyd George's 'People's Budget', which was to be a central plank of his war on poverty. This budget was redistributionary while being relatively budget-neutral, although it is worth noting that public sector net lending was negative in 1909, after being positive for the previous two years. Thus,

> "[Lloyd George] described his Budget as a 'war budget' for waging 'implacable warfare against poverty and squalidness'. His friends hailed it as 'the People's Budget'; his enemies saw it as being a war budget against property and denounced it as socialistic." (Peden, 1991, pp. 25).

As a matter of fact, the increased taxation in the 'People's Budget' did not fall on the working or middle classes, and instead were made up of super-taxes and land value taxes on those parts of the income distribution which may be assumed to have a low marginal propensity to consume out of current income. If we allow for a stimulating effect of redistribution – particularly during an era of extreme inequality – then the 'People's Budget' may account for the positive aggregate demand shock listed in table 1.

B.4 1915 – 1918

The positive aggregate demand shocks in 1915 – 1918 listed in table 1 are, of course, explained by the First World War. During this period, government expenditure and borrowing rapidly increased to pay for the war effort. At the same time, the Gold Standard was suspended, allowing substantial increases in money stocks and credit aggregates – although the Bank rate was actually higher during the War than directly preceding it. This is still the era of public finance that pre-dates demand management. Treasury officials in 1914 were quick to advise Lloyd George – still the Chancellor of the Exchequer – that in the past, "nearly half the cost of wars had been met from taxation", and that he should not rely too heavily on borrowing (Peden, 1991, pp. 38-40). However,

> "Lloyd George, who cared very little for conventional financial wisdom, chose not to follow this advice, and set himself the more modest task of raising enough revenue to pay for normal expenditure in peace, plus a margin to pay for the interest on loans raised to pay for the war." (Peden, 1991, pp. 40).

Hence the succession of large aggregate demand shocks from 1915 – 1918, which apparently constituted a novel event in the history of British war financing.

B.5 1919 – 1921

The UK in 1919 – 1921 underwent a sequence of varied shocks according to table 1, with a negative demand shock in 1919, a positive demand shock in 1920, and a negative demand shock in 1921. This reflects the extreme volatility in this period, where inflation fell from 22% to 10.1% from 1918 to 1919, jumping back to 15.4% in 1920, then falling in the deflationary years of the 1920s to -8.6% and -14% in 1921 and 1922. Similarly, the unemployment rate jumped from 0.65% in 1918 to 3.02% in 1919, fell back to 1.95% in 1920, before rising to 11.02% in 1921.

The negative demand shock in 1919 implied by these movements in inflation and unemployment can easily be explained by the end of the First World War. Government consumption, unsurprisingly, fell rapidly between 1918 and 1919, and public sector borrowing, having risen continuously during the War, was also heavily cut back in 1919. At the same time, the positive labor supply shock resulting from demobilization at the end of 1918 and 1919 should not be discounted as a partial explanation of the unexpected rise in unemployment during 1919, and in principle this goes some way in accounting for the unexpected fall in inflation.

The positive demand shock of 1920 can be assigned to the post-war boom, driven in the main by an expansion of trade and shipping following the end of the War. In turn, the major deflation of the early 1920s is usually attributed to monetary and fiscal austerity in an attempt to return to the Gold Standard at pre-war parity, which was eventually achieved in 1925. Both the bank rate and gilt rates increased from 1919 to 1920, with both the nominal and real exchange rates rising rapidly from 1921 onwards. Even more dramatic was the increase in the real interest rate, which rose precipitously from 1920 to 1921. These events may be taken as proximate causes of the 1921 negative demand shock, although the scale of the deflation is still quite impressive given the relatively modest movements in monetary and fiscal policy.

B.6 1927 – 1928

1927 and 1928, according to table 1, saw a positive supply shock and negative demand shock, respectively. As discussed in more detail in the main body of text, the positive aggregate supply shock in 1927 can be explained by a sudden fall in the bargaining power of workers following the 1926 general strike, after which the Trade Disputes and Trade Unions Act (1927) and the Unemployment Insurance Act (1927) were passed. The former Act incorporated a number of provisions to prevent unions acting in a "political" manner, including restrictions on union funding of the Labour Party, and made secondary strike action illegal. The latter Act did, in principle, embody a number of provisions which would improve the welfare of unemployed workers. However, it also required all claimants to prove that they were seeking work. As the costs and associated debt of the Unemployment Fund increased, this led the government to tighten up the eligibility process. Thus,

> "What followed was a systematic campaign to tighten up the existing administration of unemployment insurance. The 'seeking work' test, of course, had already made its mark. By 1927 one in ten of all claimants was being refused benefit because of an 'unsatisfactory attitude to work'. But thereafter the test was applied with particular severity." (Garside, 1990, pp. 48).

This tightening of the administration of unemployment insurance, alongside the new restrictions on trade union activity, constitute a clear reduction in bargaining power which may be taken to contribute to the observed supply shock in 1927. The source of the negative demand shock in 1928, meanwhile, is not as clear, as it pre-dates the 1929 Wall Street crisis.

B.7 1930 – 1931

The rapid increases in unemployment and the rate of deflation experienced in the early 1930s, leading to the implied negative demand shocks in table 1, are straightforwardly attributable to the Great Depression that followed the 1929 Wall Street crisis. As in 1907 – 1908, the effects of the Depression were transmitted through collapses in trade and capital flows, although the UK economy, having never fully recovered from the volatility of the 1920s, started out from a low base. Whether or not the continued collapse of trade volumes constituted an endogenous response to the crisis, or a secondary exogenous shock resulting from the imposition of trade barriers, is controversial. However, it is worth noting that the Hawley-Smoot Tariff Act of 1930 in the USA and the Abnormal Importation Act of 1931 in the UK coincide with the negative demand shocks listed in table 1 during this period. At the end of this period, a final negative demand shock occurred in the form of a deflationary budget, with unemployment benefits and public sector wages both cut by the incumbent Labour government. As well as adding further deflationary pressure to the economy, this resulted in a political crisis and National Government at the end of 1931.

B.8 1938

Re-armament in preparation for the Second World War is generally considered to be the proximate cause behind the recovery in employment after the early 1930s. However, tight fiscal and monetary policy by the Roosevelt administration during this period led to a recession from 1937 – 1938 in the USA, which may be taken to be the source of the negative aggregate demand shock in table 1 in 1938. Thus Harry Richardson, in *Economic Recovery in Britain 1932 – 1939*, argues that,

> "There had been a lull in the American recovery from the end of 1936, Wall Street had looked very shaky at least since the spring of 1937 and industrial activity in the United States turned downwards in the late Summer. In Britain, on the other hand, some indicators continued to move upwards while others fell in the second half of 1937, and only at the end of the year was a check to recovery generally admitted. On first sight, it looks as if this is the usual sequence of recession being transmitted to the United Kingdom from the United States." (Richardson, 1967, pp. 31).

Richardson goes on to argue that the recession of 1937-8 was, "as much due to internal causes as to depression abroad" (Richardson, 1967, pp. 31). But we are chiefly interested in the exogenous movements here; internal movements (i.e., those predictable given the information set) are already taken into account in the VAR model.

B.9 1939 – 1941

As with the positive aggregate demand shocks from 1915 – 1918, the positive aggregate demand shocks in 1939 and 1940 are easily attributable to the increases in government expenditure and borrowing to pay for the Second World War. The return to a full employment War economy via planning is also of obvious importance, and a sudden increase in centrally planned employment allocation alongside price controls would manifest itself as a demand shock given our identification assumptions, even though the New Keynesian model does not reflect these institutional arrangements. The positive aggregate supply shock of 1941 listed in table 1 is somewhat more puzzling, and coincides with the sharp decrease in the inflation rate during this period.

B.10 1946 – 1947

According to table 1, the UK suffered a negative supply shock in 1946 and enjoyed a positive demand shock in 1947. The negative supply shock is difficult to square with historical events. On the face of it, one would expect a negative demand shock to have occurred at the close of the War, as in 1919. Government expenditure and borrowing were reduced with demobilization, and the latter should have been expected to reduce inflation alongside the increase in unemployment. At the same time, the economy was still subject to widespread planning, import quotas, and price control during this period, and as noted above the New Keynesian model is not designed to account for movements in prices and employment under these institutional arrangements.

Unfortunately, the positive demand shock of 1947 in table 1 is as difficult to account for as the negative supply shock of 1946. One of the most well-known events in 1947 is the coal crisis at the beginning of the year. Cairncross (1985), for example, notes that a large part of the manufacturing industry had to shut down for lack of power during the crisis, leading to a shortage of steel and other materials. Similarly, Dow (1964) reports that the crisis led to the weekly press being halted for two weeks, and that the disruption of production led to a reduction of £200 million in export earnings (Dow, 1964, pp. 22). This is a classic example of a supply shock, but, according to table 1, unemployment was unexpectedly low in this year. Again, the transitory nature of this period, as well as the multitude of controls and quotas in force, apparently make it difficult for the AD-AS model's predicted shocks to square with the narrative record.

B.11 1951

In contrast to the ambiguity of the immediate post-war years, the period 1950-51 is a classic episode of high aggregate demand pressure, caused in the main by the outbreak of the Korean War. As Dow (1964) notes,

> "In a world already heading for a boom, this caused the sharpest burst of inflation in the post-war period, and world-wide shortage of materials. To the United Kingdom it brought rising prices; a major increase in defence spending; and within a year, a balance of payments crisis." (Dow, 1964, pp. 54-55).

Thus, part of the 1951 positive aggregate demand shock listed in table 1 can be attributed to a sharp increase in global aggregate demand, and part can be attributed to an increase in domestic defence expenditure. At the same time, as Dow points out, both the rapid recovery of Western Germany in 1949-1950 and the recovery of the USA from its 1949 recession had put a great deal of pressure on raw materials prices during this period.

B.12 1953

By 1953 the economic repercussions of the Korean boom had come to an end, and the post-war consensus of Butskellism in demand management was firmly established. Whereas the sources of the 1951 demand shock are quite obvious, there is no obvious global or domestic event in 1953 that corresponds to the positive aggregate supply shock listed in table 3. However, Dow (1964) notes that falling import prices had, "greatly slowed down the rise in retail prices", which is consistent with the large negative inflation residual in 1953 (Dow, 1964, pp. 75).

B.13 1974 – 1975

Interestingly, the Barber Boom of the early 1970s is not listed in table 1, and one might imagine that 1974, at least, would show the negative effects of the 1973 Yom Kippur War and subsequent OPEC embargo as a negative aggregate supply shock. However, as discussed in more detail in the main body of the text, it is well established that UK fiscal policy was expansionary during 1974, with a 250% increase in the public sector borrowing requirement from 1974 – 1976 coinciding with a "crisis of public expenditure" in the mid-1970s (Tomlinson, 1985, pp. 130). In November of 1974, in the face of a sharp increase in inflation, the Labour Chancellor Denis Healey could state that,

> "Yet there is no real evidence that in this situation the adoption of deflationary policies will produce a worthwhile impact on the rate of inflation – at any rate within a time scale that democracy will tolerate." (quoted in Tomlinson, 1985, pp. 171).

Participants in the bond market appeared to have disagreed, with a market consensus that government borrowing was too high during this period leading to a gilt strike in 1976 (Tomlinson, 1985, pp. 132). In addition, figure 1 in Cloyne (2013) shows a number of exogenous (and endogenous) tax cuts during the early to mid-1970s that are derived from the UK budget statements published during this period. Thus, the positive aggregate demand shocks in 1974 and 1975 listed in table 1 can be explained by (relatively) expansionary fiscal policy, which in turn can be interpreted as a conscious attempt by the Labour government to mitigate the impact on employment of the negative cost pressures induced by the 1973–4 oil price crisis.

B.14 1978

Inflation fell continuously in the UK from 1975 to 1978, with the largest fall between 1977 and 1978. While the relative stability in the dollar oil price from 1975 to 1978 will mechanically serve to reduce consumer price inflation, in itself it does not constitute the positive supply shock listed in table 1. Instead, we can attribute this shock to Labour's Social Contract, in which unions limited wage increases in return for various pieces of legislation (see Backhouse & Forder (2013) for a brief history of post-war incomes policies and their rationale). This policy coincided with the 1975 to 1978 period of falling inflation, and although it can hardly be considered as unexpected by the general public – it contributed, in part, to the Winter of Discontent – it is certainly not the type of systematic macroeconomic policy that can be considered endogenous in a parsimonious model. It can therefore be taken as an example, albeit an unusual example, of a negative aggregate supply shock.

B.15 1979 – 1981

The obvious explanation for the negative supply shocks listed in table 1 in 1979, 1980, and 1981 are the start of the Iranian revolution (December 1978 to January 1979) and the outbreak of the Iran-Iraq War (September 1980 to October 1980). These events are discussed in the context of identifying oil market shocks in Antolín-Díaz & Rubio-Ramírez (2018), and the subsequent oil price rises are generally acknowledged to be the proximate causes of the increases in unemployment and inflation in the UK during this period.

B.16 1991

The recession in the early 1990s saw inflation jumping from 5.23% in 1989 to 6.97% in 1990, and then to 7.53% in 1991, before falling back to 4.26% in 1992. Unemployment also increased from 1990 to 1991, but did not peak until 1993, at 10.37%. These shifts in unemployment and inflation, with the former lagging the latter, explain the implied negative supply shock in table 1. Ironically, this recession followed the "Lawson Boom" in which extensive supply side reforms were believed to have paved the way for a prolonged expansion. Thus Nigel Lawson, in his 1988 budget speech, could confidently state that,

> "The plain fact is that the British economy has been transformed. Prudent financial policies have given business and industry the confidence to expand, while supply side reforms have progressively removed the barriers to enterprise."[7]

However, the boom led to bust, with house prices reaching their peak in 1989. While the bulk of the events around this period point towards a natural end to an expansion, including the fall in house prices, and some negative aggregate demand shocks, including the ERM entrance in 1990 and deflationary monetary policy from 1992 onwards, the negative aggregate supply shock in table 1 can be explained by the adverse oil price shock engendered by the outbreak of the first Gulf War in August 1990. This view of the recession was not uncommon at the time, for example,

> "Although special factors (food, oil) are partly to blame, the main reason for the scale and tenacity of today's inflation problem is undoubtedly the vibrant nature of the Lawson Boom. That boom, one of the most vigorous of all post-war upturns, left a lingering legacy of inflation which finds expression in an oversized balance-of-payments deficit, persistent capacity problems, and, by European standards, an untypically low level of unemployment." (Martin, 1991, pp. 29).

As in 1938, therefore, the bulk of the 1991 recession is explainable by internal developments, with a negative shock exacerbating the situation.

B.17 2009

The last large shock listed in table 1 is the negative aggregate demand shock in 2009. This coincides with a significant global recession, which followed the financial crisis of 2008. As with the negative demand shocks following the 1907 financial crisis and the Great Depression in the early 1930s, the source of this shock was the USA, with its effects being transmitted through financial contagion channels between Wall Street and the City of London. At the same time, global trade volumes rapidly contracted, with the Baltic Dry Index collapsing between the end of 2008 and the beginning of 2009. Unlike during the Great Depression, however, a large coordinated response from governments and central banks prevented the recession turning into a depression, explaining the lack of any further negative shocks in table 1 after 2009.

[7] From Lawson's 1988 budget speech – see e.g., the speech archive at the Margaret Thatcher Foundation website, www.margaretthatcher.org.

C VAR estimation with impulse indicator saturation

Table C1: **VAR(2) in unemployment and inflation rate, impulse indicator saturation**

	< 10%	< 10%	< 5%	< 5%	< 1%	< 1%
	u_t	π_t	u_t	π_t	u_t	π_t
u_{t-1}	1.514***	-0.581***	1.394***	-0.509***	1.448***	-0.973***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
u_{t-2}	-0.560***	0.485***	-0.469***	0.436***	-0.523***	0.946***
	(0.000)	(0.006)	(0.000)	(0.003)	(0.000)	(0.000)
π_{t-1}	0.129***	0.755***	0.128***	0.697***	0.085***	0.893***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
π_{t-2}	-0.103***	-0.009	-0.079***	0.036	-0.062***	-0.092
	(0.000)	(0.878)	(0.000)	(0.505)	(0.001)	(0.279)
1900	0.588	3.575***	0.564	3.364***		
	(0.153)	(0.002)	(0.225)	(0.008)		
1901	0.586	-4.414***	0.681	-4.226***		
	(0.163)	(0.000)	(0.148)	(0.001)		
1904	1.003**	-1.852*	1.170**	-1.949		
	(0.015)	(0.100)	(0.011)	(0.119)		
1905	-0.844**	0.624				
	(0.045)	(0.589)				
1906	-1.016**	-1.373				
	(0.013)	(0.219)				
1908	2.953***	-1.265	2.976***	-1.241	3.003***	-1.854
	(0.000)	(0.258)	(0.000)	(0.321)	(0.000)	(0.440)
1909	-0.914**	-0.145				
	(0.041)	(0.906)				
1910	-1.696***	1.536	-1.507***	1.287	-1.628***	1.595
	(0.000)	(0.172)	(0.001)	(0.302)	(0.003)	(0.506)
1911	-0.220	-2.987***	-0.250	-2.929**		
	(0.597)	(0.009)	(0.592)	(0.021)		
1913	-0.226	-2.864**	-0.224	-2.777**		
	(0.581)	(0.011)	(0.628)	(0.027)		
1915	-2.236***	9.291***	-2.237***	9.348***	-2.199***	8.866***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1916	-0.856*	6.330***	-1.114**	7.015***		
	(0.074)	(0.000)	(0.032)	(0.000)		

Notes: In the first row, the percentages are the cut-off for indicator retention; p-values are in parentheses.

Table C2: **VAR(2) in unemployment and inflation rate, impulse indicator saturation (continued)**

	< 10%	< 10%	< 5%	< 5%	< 1%	< 1%
	u_t	π_t	u_t	π_t	u_t	π_t
1917	-0.717	10.007***	-1.082**	10.505***	-0.562	8.535***
	(0.119)	(0.000)	(0.032)	(0.000)	(0.328)	(0.001)
1918	-1.432***	1.879	-1.850***	2.497*		
	(0.004)	(0.165)	(0.001)	(0.090)		
1919	1.895***	-7.500***	1.309**	-7.395***	1.742***	-8.113***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.003)	(0.002)
1920	-1.463***	8.047***	-1.719***	7.442***	-1.863***	9.657***
	(0.003)	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)
1921	8.644***	-21.841***	8.341***	-21.406***	8.808***	-23.459***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1922	-3.382***	-3.287	-2.661***	-5.188**	-3.860***	2.888
	(0.000)	(0.141)	(0.001)	(0.014)	(0.000)	(0.418)
1923	0.274	3.380***	0.585	2.792**		
	(0.553)	(0.008)	(0.253)	(0.044)		
1924	-0.388	2.265*				
	(0.408)	(0.078)				
1925	0.766*	-0.348				
	(0.074)	(0.767)				
1927	-2.092***	-1.903*	-1.803***	-2.214*	-1.976***	-1.648
	(0.000)	(0.097)	(0.000)	(0.079)	(0.000)	(0.495)
1928	2.181***	-0.180	2.177***	-0.351	2.107***	-0.979
	(0.000)	(0.876)	(0.000)	(0.784)	(0.000)	(0.688)
1930	4.304***	-2.933***	4.459***	-3.133**	4.353***	-3.142
	(0.000)	(0.009)	(0.000)	(0.012)	(0.000)	(0.190)
1931	2.202***	-0.613	2.862***	-1.188	2.461***	1.037
	(0.000)	(0.660)	(0.000)	(0.395)	(0.000)	(0.691)
1932	-0.818	2.495*				
	(0.120)	(0.084)				
1933	-1.312***	0.160				
	(0.004)	(0.897)				
1934	-0.897**	0.803				
	(0.038)	(0.500)				
1936	-0.898**	-0.587				
	(0.031)	(0.606)				

Notes: In the first row, the percentages are the cut-off for indicator retention; *p*-values are in parentheses.

Table C3: **VAR(2) in unemployment and inflation rate, impulse indicator saturation (continued)**

	< 10%	< 10%	< 5%	< 5%	< 1%	< 1%
	u_t	π_t	u_t	π_t	u_t	π_t
1938	2.196***	-2.356**	2.230***	-2.298*	2.363***	-3.713
	(0.000)	(0.039)	(0.000)	(0.070)	(0.000)	(0.125)
1939	-3.957***	1.855	-3.670***	1.503	-3.824***	2.274
	(0.000)	(0.109)	(0.000)	(0.235)	(0.000)	(0.349)
1940	-0.823*	12.159***	-1.050**	12.283***		
	(0.071)	(0.000)	(0.033)	(0.000)		
1941	-2.359***	-4.256***	-2.600***	-3.352**	-1.864***	-7.488***
	(0.000)	(0.003)	(0.000)	(0.029)	(0.003)	(0.005)
1942	0.725	-3.124**	0.144	-3.195**		
	(0.139)	(0.020)	(0.775)	(0.020)		
1943	0.262	-3.480***	-0.072	-3.550***		
	(0.544)	(0.003)	(0.879)	(0.006)		
1946	1.327***	-0.262	1.248***	-0.252		
	(0.001)	(0.817)	(0.007)	(0.842)		
1947	-1.504***	4.293***	-1.402***	4.207***	-1.487***	5.003**
	(0.000)	(0.000)	(0.003)	(0.001)	(0.008)	(0.041)
1949	-0.484	-4.159***	-0.634	-4.079***		
	(0.239)	(0.000)	(0.171)	(0.001)		
1950	0.701*	0.591				
	(0.097)	(0.610)				
1951	-0.718*	5.060***	-0.741	5.092***		
	(0.079)	(0.000)	(0.109)	(0.000)		
1953	-1.269***	-5.098***	-1.373***	-4.992***		
	(0.002)	(0.000)	(0.003)	(0.000)		
1974	-0.077	7.379***	-0.234	7.536***		
	(0.853)	(0.000)	(0.616)	(0.000)		
1975	-0.219	9.882***	-0.357	10.281***		
	(0.619)	(0.000)	(0.471)	(0.000)		
1979	0.586	4.976***				
	(0.187)	(0.000)				
1980	0.885**	5.713***	0.826*	5.910***		
	(0.035)	(0.000)	(0.081)	(0.000)		
Constant	0.160	1.375***	0.202*	1.391***	0.287**	1.079*
	(0.158)	(0.000)	(0.095)	(0.000)	(0.031)	(0.063)

Notes: In the first row, the percentages are the cut-off for indicator retention; *p*-values are in parentheses.

D VAR estimation with intercepts

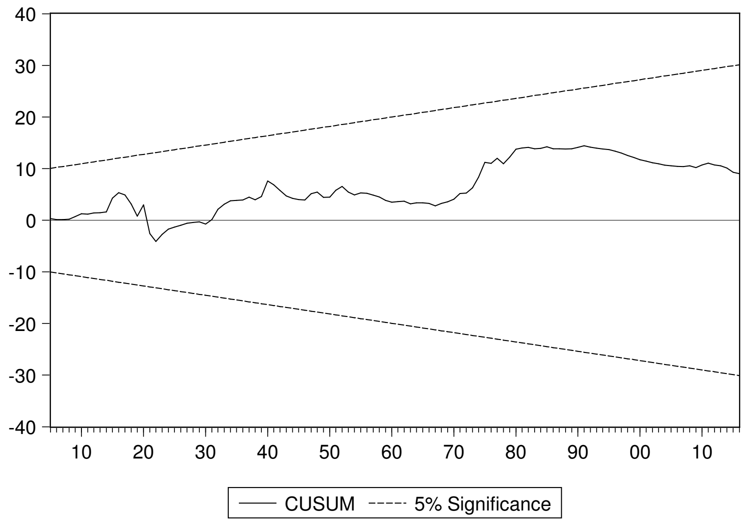

Figure D1: CUSUM test output, inflation equation (including intercept).

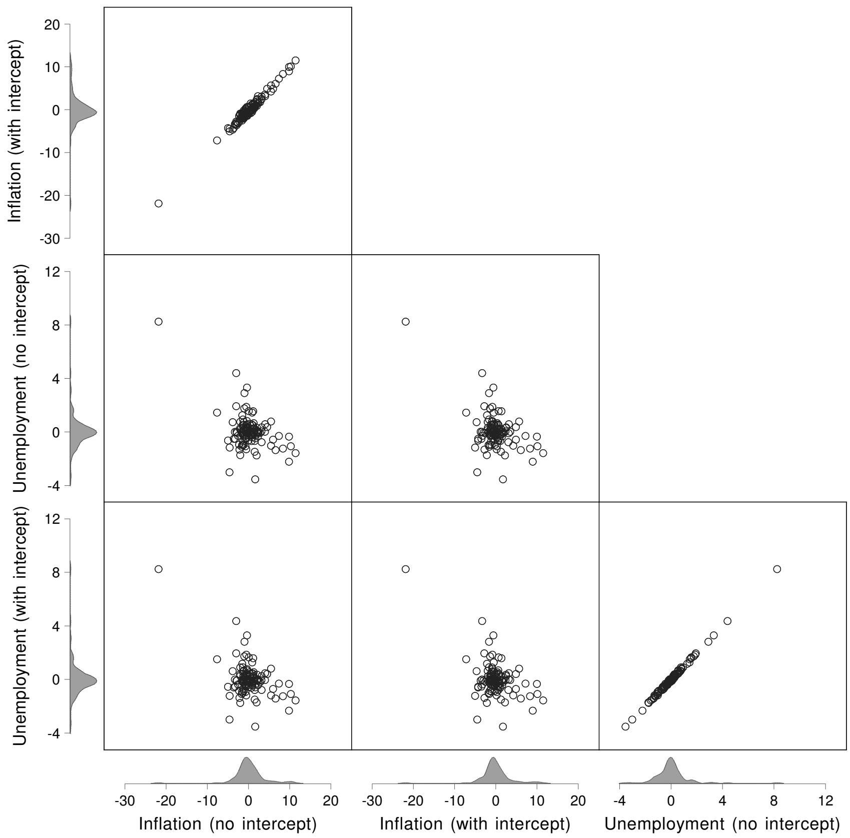

Figure D2: Scatter matrix and kernel densities for residuals from VAR models estimated with and without intercepts.