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Abstract

This article contributes new time series for studying the UK economy during World War I and the interwar period. The time series are per capita hours worked and average capital income, labor income, and consumption tax rates. Uninterrupted time series of these variables are provided for an annual sample that runs from 1913 to 1938. We highlight the usefulness of these time series with several empirical applications. The per capita hours worked data are used in a growth accounting exercise to measure the contributions of capital, labor, and productivity to output growth. The average tax rates are employed in a Bayesian model averaging experiment to reevaluate the Benjamin and Kochin (1979) regression.

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Key Words: Hours worked; Average tax rates; Growth accounting; Bayesian model averaging.

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1. Introduction

Macroeconomics arguably exists as a field of economics because the UK suffered two depressions between the world wars. Keynes (1964, pp. 2–3) acknowledges that *The General Theory* is his response to interwar UK economic outcomes and policies. Critiques of Keynesian as well as non-Keynesian theories of the interwar UK economy are plentiful. Unfortunately, researchers are often constrained from applying modern quantitative methods to evaluate these theories because the necessary time series either do not exist or are corrupted by missing observations.

This paper aims to relax the data constraint by contributing previously unavailable UK fiscal and labor market time series for an annual sample beginning in 1913 and ending with 1938. The fiscal variables are ex post average capital income, labor income, and consumption tax rates. The labor market variable is per capita hour worked. Table 1 lists these time series.

The first part of the paper discusses data sources, tabulation methods, and additional assumptions used to tabulate UK ex post average tax rates and per capita hours worked time series. Computing ex post average tax rates involves dividing capital income, labor income, and consumption tax revenue by capital income, labor income, and consumption expenditures, respectively. Feinstein (1972) and Mitchell (1988) contain these data in one way or another for the entire 1913–1938 sample.

In contrast, aggregate UK labor market data are missing in the 1913–1938 sample. These data are needed to construct UK per capita hours worked. A key source for UK aggregate labor market data is Matthews, Feinstein, and Odling-Smee (1982), but they report aggregate hours worked only for 1913, 1924, and 1937. We fill in missing observations from 1914 to 1923 by accounting for a long-run decline in hours worked during this period; see Clapham (1932), Dowie (1975), and Matthews, Feinstein, and Odling-Smee (1982). Between 1924 and 1938, an uninterrupted per capita hours worked series is computed by adopting the fixed annual change in hours worked assumption of Cole and Ohanian (2002a). The resulting series runs uninterrupted from 1913 to 1938. This is our preferred measure of per capita hours worked that is reported in table 1.

Table 1 also reports an alternative per capita hours worked series. We gauge the robustness of the assumptions used in calculating our preferred per capita hours worked measure with this alternative. Our preferred and alternative per capita hours worked series are identical before 1920. From 1920 to 1938, the alternative per capita hours worked series is derived from indices of 'normal weekly hours' taken from the Ministry of Labour *Gazette* (September 1957) and the 1924 and 1937 aggregate hours worked observations of Matthews, Feinstein, and Odling-Smee (1982). Thus, differences in these series between 1920 and 1938 reflect assumptions employed in their construction. However, these disparities appear not to be substantial because moments of our preferred and alternative per capita hours worked series are nearly identical whether computed on a 1916–1938 sample, the interwar 1920–1938 sample, or a shorter 1925–1938 interwar sample.

The average tax rate and per capita hours worked time series fill in gaps that have inhibited using time series econometrics, calibration tools, and dynamic stochastic general equilibrium (DSGE) models to study UK fiscal policy and labor markets whether on the interwar period, 1920–1938; the 'transwar' years, 1913–1924; or a 1916–1938 sample. For example, we engage unit root tests to describe average tax rate persistence. The tests indicate that average capital income and consumption tax rates are observationally equivalent to unit root processes on a 1916–1938 sample, but the average labor income tax rate is not. Although Bizer and Durlauf (1990) and Hess (1993), among others, assess the optimality of fiscal policy with unit root tests of tax rates, Scott (2007) shows that these tests are insufficient to judge this hypothesis.

Nason and Vahey (2007) give context for unit root tests of the average tax rates. Their analysis shows that the UK moved to a fiscal policy regime, the McKenna rule, in 1916 that was a commitment to smooth the paths of government debt and debt retirement. The evidence is that the UK remained committed to the McKenna rule during the transition from World War I to the peacetime of the 1920s and that this commitment continued into the 1930s. Given the commitment to smooth debt during the life of the McKenna rule, a tax rate has to act as the fiscal buffer to close the UK government budget constraint. Capital income taxation played this role according to Nason and Vahey (2007). The persistence of the average capital income tax rate, along with this tax rate's level and volatility, are consistent with Nason and Vahey's view of UK fiscal policy from 1916 to 1938.

Next, we present an application to exploit the uninterrupted per capita hours worked times series. Our preferred measure of per capita hours worked is used in a growth accounting exercise to construct UK total factor productivity (TFP) from 1916 to 1938. Labor input is measured with total hours worked, which equals per capita hours worked multiplied by the employment rate. The growth accounting exercise finds that TFP growth is constant across 1916–1938 and interwar samples. There is also little change in the average growth rate of the capital stock across these samples. In contrast, the average growth rate of total hours worked is negative on the 1916–1938 sample and only turns positive when observations from 1916 to 1924 are excluded. Average output growth is positive on 1916–1938, 1920–1938, and 1925–1938 samples. The latter sample yields the greatest average output growth. Thus, our growth accounting exercise generates evidence that is consistent with earlier accounts by Bienefeld (1972), Dowie (1975), Broadberry (1986, 1990), and more recently Cole and Ohanian (2002a) that focus on the labor market to explain the poor performance of the interwar UK economy. However, the uninterrupted per capita hours worked time series is necessary to discover that the drop in output following World War I coincided with negative labor input growth and that the expansion of the 1920s occurred at the same time labor input growth turned positive.

The usefulness of the average tax rate data is displayed in an application that revisits the Benjamin and Kochin (1979) regression. Benjamin and Kochin (BK) estimate a regression to test their hypothesis that larger unemployment benefits contributed to a higher UK unemployment rate during the interwar period. Although many questions have been raised about the specification of the BK regression, this regression has not been subjected to a Bayesian model evaluation. We employ Bayesian model averaging (BMA) methods to quantify uncertainty surrounding the BK estimates of the response of the UK unemployment rate to the ratio of unemployment benefits to wages, the replacement ratio, for 1916–1938 and 1920–1938 samples. The BMA exercises quantify this uncertainty by enlarging the space of the BK regression model with specifications that add different combinations of the average tax rates. The average tax rates represent uncertainty in the regressors that explain variation in the UK unemployment rate conditional on the estimation samples. Given these samples, the BMA exercises reveal that the BK estimates of the response of the UK unemployment rate to the replacement ratio are fragile, especially with respect to the average capital income tax rate.

The paper follows this order. Section 2 describes our contributions to the World War I and interwar UK time series. We present two applications in section 3 that use the per capita hours worked and average tax rate data. The final section concludes.

2. UK Average Tax Rates and Per Capita Hours Worked, 1913–38

This section describes the construction of UK average capital income, labor income, and consumption tax rates and per capita hours worked. The data are sampled at an annual frequency. The sample begins in 1913 and ends with 1938.[1] We conduct some preliminary analyses of these time series to close this section, which draw attention to the importance of understanding the data prior and subsequent to 1920.

[1]The sample period covers Irish independence from the UK. We follow conventions established by Feinstein (1972) and Mitchell (1988) that exclude Eire's contribution to post-1919 data.

2.1 *Average Tax Rates During World War I and the Interwar Period*

Table 1 lists ex post average capital income, labor income, and consumption tax rates from 1913 to 1938. These tax rates are plotted in figure 1. The focus is on ex post average tax rates because ex ante and ex post UK marginal tax rates are unavailable for this sample. Our approach to computing ex post average tax rates follows Cooley and Ohanian (1997). They compile ex post annual average UK tax rates for World War II and its post-war period by dividing revenue of a tax source by the related income or expenditure series.

Feinstein (1972) and Mitchell (1988) are the primary sources for the data used to compute the average tax rates. We discuss the numerator and denominator of an average tax rate separately to be explicit about its construction.[2] Average tax rates are reported on a calendar year (CY) basis. We convert from the fiscal year (FY) to the CY with $CY_t = 0.25FY_t + 0.75FY_{t+1}$.

The average capital income tax rate is the ratio of capital income tax revenue to capital income. Mitchell (1988) is the source of pre-1920 capital income and capital income tax revenue. Capital income tax revenue includes death duties found in Mitchell (pp. 583–584) from 1913 to 1919. By 1913, death duties were already a "long-established method" of capital taxation in the UK; see Daunton (2002, p. 212).[3] Pre-1920 capital income is gross trading profits from Mitchell (pp. 829–830). This income is about 60 percent of total corporate income post-1919. The ratio of pre-1920 capital income tax revenue to pre-1920 capital income is the average capital income tax rate, $\tau_{K,t}$, from 1913 to 1919.[4]

Feinstein (1972) lacks capital income tax revenue and income before 1920 but has these data for the interwar period.[5] From 1920 to 1938, capital income tax revenue is the sum of taxes levied on corporate income plus other taxes paid by capital, including death duties. These data are provided by Feinstein (T77 and T79, respectively).[6] Capital income is matched to corporate income post-1919, which is also found in Feinstein (T77). We splice pre-1920 $\tau_{K,t}$ to the 1920–1938 ratio of capital tax revenue to capital income to generate $\tau_{K,t}$ for the 1913–1938 sample.

Calculation of $\tau_{K,t}$ excludes revenue generated by the Excess Profit Duty (EPD). The budget of September 1915 includes an announcement that the EPD would be implemented in 1916. The EPD is a unique part of the UK's World War I fiscal policy regime, which is known as the McKenna rule for the

[2]The numerators and denominators are in nominal terms (*i.e.*, current year pounds).

[3]Death duties fell on personal property from the late 1880s to the 1930s; see Daunton (2002, p. 8).

[4]Table 1 of Arnold (1999) contains indices of profits in current prices from 1889 to 1924. The third column of table 1 lists an index that matches our concept of capital income taken from Mitchell (1988) and Feinstein (1972).

[5]The 'List of Table' in Feinstein (1972) is prefixed by T.

[6]Death duties are on average about 50 percent of capital tax revenue from 1920 to 1938, but this ratio rises from less than 50 percent in the early 1920s to around 60 percent by 1938.

then Chancellor of the Exchequer, Reginald McKenna. Citing Daunton (2002) among others, Nason and Vahey (2007) present evidence that the McKenna rule regime operated from 1916 to 1938.[7]

The McKenna rule consists of several pieces. Among the most important features are a commitment to smooth a state-contingent path of debt and debt retirement subsequent to the end of World War I, year-by-year budget balance on nondefense expenditures, and use of the EPD to prevent excess 'war profits'.[8] In McKenna's September 1915 budget, EPD revenue is generated by confiscating 50 percent of a covered firm's profits, net of labor costs and investment, that is in excess of average 1912–1913 profits plus £100. According to this scheme, EPD revenue equals net profits multiplied by the EPD statutory rate. This revenue stream is the numerator of the average EPD rate, $\tau_{EPD,t}$. The denominators of $\tau_{EPD,t}$ and $\tau_{K,t}$ are equivalent, which permits aggregation of these tax rates. As previously noted, the EPD was 50 percent initially, but it was raised to 60 percent in McKenna's budget of late 1916 and to 80 percent by Bonar Law in his 1918 budget. The 1919 budget of Austen Chamberlain lowered the EPD with the end of World War I as the McKenna rule mandated. However, the EPD was not abolished by legislation until 1921.

The UK war budgets of 1916–1918 lean heavily on the EPD. It contributes 24, 30, and 32 percent of government revenue in 1916, 1917, and 1918, respectively. Although summing $\tau_{EPD,t}$ and $\tau_{K,t}$ gives an indication of the total capital tax effort, these taxes created different economic incentives for firms and households during World War I and the immediate post-war years that suggest it is reasonable to treat the two tax rates as distinct. This helps for comparing $\tau_{EPD,t}$ and $\tau_{K,t}$ to the average labor income and consumption tax rates. We include $\tau_{EPD,t}$ in table 1 and figure 2 to enable these comparisons.[9]

The average labor income tax rate is straightforward to compute from available revenue and tax base data. Feinstein (1972, T5–6) provides employment income, which is identified as the labor income tax base. Labor income tax revenue is the income tax revenue series of Feinstein (T31–32), subsequent to netting for EPD, and corporate tax revenue that is also found in Feinstein (T31–32). The ratio of labor tax revenue to labor income equals the average labor income tax rate, $\tau_{N,t}$.

[7] Nason and Vahey (2007) use a permanent income model to show the McKenna rule's detrimental effect on the UK economy.

[8] The McKenna rule intended for the UK fiscal authority to employ the EPD only for the duration of World War I; see Daunton (2002, pp. 55–57). He argues that policymakers viewed the EPD as a device to mitigate war profits and monopolistic rents thought to be caused by temporary excess demand during World War I.

[9] Although the EPD was eliminated in 1921, table 1 and figure 2 show $\tau_{EPD,t}$ falling to zero from 1922 to 1927. The reason is that we add to the EPD the revenue from a corporate profits tax that was introduced in the 1920 budget; see Daunton (2002, p. 91). This tax was part of the transition from the EPD to peacetime capital income taxation. The 1920 budget set the corporate profits tax rate at 5 percent. Mitchell (1988, p. 586) reports that the corporate profits tax raised £17.6 million in 1922. This was less than 60 percent of the £30.5 million generated by the EPD in 1922, which was the last year of the EPD. The 1924 budget eliminated the corporate profits tax, but only after its rate was cut in half by the 1923 budget; see Daunton (pp. 92–93). The corporate profits tax provided the Treasury with a shrinking revenue stream through 1927.

A similar ratio defines the average consumption tax rate, $\tau_{C,t}$. Its numerator is expenditure tax revenue that is composed of customs and other duties and post office, telephone, telegraph, and motor vehicle excise taxes from Mitchell (1988, pp. 583–584). The consumption tax base is household goods and services expenditures as listed in Mitchell (pp. 833–834).

We plot $\tau_{K,t}$, $\tau_{N,t}$, $\tau_{C,t}$, and $\tau_{EPD,t}$ from 1913 to 1938 in figure 1. In this figure, the average tax rates are denoted $\tau_{K,t}$, $\tau_{N,t}$, $\tau_{C,t}$, and $\tau_{EPD,t}$ with a solid (red) line, dashed (green) line, dot-dash (brown) line, and solid (gray) line with circles, respectively.

UK fiscal policy holds $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ almost equal between 1913 and 1915, according to table 1 and figure 1. However, $\tau_{N,t}$, and $\tau_{C,t}$ rise slightly in 1915. These changes in average tax rates are the product of the initial World War I budgets for the UK that attempted to maintain 'business as usual' and not disadvantage any interest or class; Daunton (2002, pp. 38–40 and p. 55).

Higher levies are placed on profits and to a lesser extent labor income beginning in 1916. Table 1 reports that $\tau_{EPD,1916} = 13.1$ percent, which is almost double the next largest average tax rate, $\tau_{N,t}$, in that year. Subsequently,$\tau_{EPD,t}$ falls to about 15 percent in 1921 before becoming negligible by the mid-1920s, which is also seen in figure 1.

The inclination to tax capital more than labor income or consumption remains a cornerstone of UK fiscal policy during the interwar years. The EPD is supplanted by direct capital income taxation in 1921. Table 1 shows that $\tau_{K,t}$ reached 26.4 percent in 1921 from just 3 percent in 1918.[10] The sharp rise in the average capital income tax rate in the early 1920s is consistent with after-tax real returns on capital reported in Arnold (1999).[11] Thus, the average capital tax rate is a reliable guide to the pressures the McKenna rule exerted on capital in the UK during the 'transwar' period. Figure 1 also depicts the shift to $\tau_{K,t}$ from $\tau_{EPD,t}$ in the early 1920s. Although $\tau_{K,t}$ falls to 14 percent in 1937, it stays above $\tau_{N,t}$ and $\tau_{C,t}$ by 4.5 percentage points or more from 1921 to 1938.

Figure 1 displays a steady rise in $\tau_{C,t}$ from 1924 to 1938. Compare this to the volatility of $\tau_{N,t}$ during the same years. Steady growth in $\tau_{C,t}$ is sufficient for it to equal or exceed $\tau_{N,t}$ by the mid-1930s. Nonetheless, figure 1 depicts larger (positive) spikes in $\tau_{K,t}$ around the economic downturns of the early 1920s and early 1930s than observed for $\tau_{N,t}$ and $\tau_{C,t}$ in figure 1. This volatility suggests that capital income taxation was an important tool of UK fiscal policy during the interwar period.

[10] The 1921 spike in $\tau_{K,t}$ would be even more striking without the contribution death duties make to UK capital income tax revenue before 1920. However, there are measurement issues inherent in tying capital taxation to death duties from 1913 to 1919 because it may create a positive bias in $\tau_{K,t}$, induced, for example, by confounding stocks with flows.

[11] The after-tax real return on capital falls from an average of 14.5 percent during 1915–1919 to 5.4 percent for 1920–1924; Arnold (1999; p. 58).

2.2 *Working in War and Peace: Per Capita Hours Worked*

Despite the attention paid to UK labor markets of the interwar years, little is known about hours worked in this period, as well as during World War I. The default sources of UK historical statistics, Feinstein (1972) and Mitchell (1988), lack uninterrupted aggregate hours worked data from 1913 to 1938. Instead, Mitchell (1988) references appendix D of Matthews, Feinstein, and Odling-Smee (1982) which gives annual aggregate hours worked observations only for 1913, 1924, and 1937.

This paper fills in the missing hours worked observations for 1914–1923, 1925–1936, and 1938. An uninterrupted 1913–1938 per capita hours worked time series is constructed by drawing on Clapham (1932) and Dowie (1975), as well as Matthews, Feinstein, and Odling-Smee (1982), Feinstein (1972), and Mitchell (1988). Matthews, Feinstein, and Odling-Smee (1982) report average hours worked per worker of 2,753, 2,219, and 2,293 for 1913, 1924, and 1937, respectively; also see Mitchell (1988, p. 147). Nonetheless, Matthews, Feinstein, and Odling-Smee (pp. 71–72) argue that their 1913 figure of 2,753 average hours worked per worker is too high. They refer to an estimate by Clapham (pp. 477–479) that the average annual reduction in hours worked is in the range of 2.5 to 5 percent from 1880 to 1914. We calibrate 1913 per capita hours worked to the midpoint of Clapham's range, which lowers this observation to 2,641 from 2,753 average hours worked per worker.

Two additional adjustments are needed to produce hours worked observations between 1913 and 1924. Evidence is presented by Matthews, Feinstein, and Odling-Smee (1982) that during this period 10 to 20 percent of the decrease in hours worked was generated by a gradual change in the composition of employment across occupational and industrial sectors. We adopt the midpoint of this range. Given this assumption, it is straightforward to apportion 15 percent of the accumulated loss in hours worked in equal amounts to each of the 11 years between 1913 and 1924.

Matthews, Feinstein, and Odling-Smee (1982) and Dowie (1975) report that hours worked fell in 1919. According to Dowie, firms began to shorten the morning shift by one hour beginning in January 1919. He finds that these changes were implemented by July 1919. Given this evidence, we attribute to 1919 the remaining 85 percent fall in hours worked that occurred between 1913 and 1924. This implies that in 1919 the average employee lost 359 [$\approx 0.85 \times (2641 - 2219)$] hours of work plus the fixed amount equally allotted to all years from 1913 to 1924. We calculate the fixed annual drop in hours worked per worker by adding the 1919 loss of 359 hours to the 1924 observation of 2,219 hours, subtracting this amount from the adjusted 1913 observation of 2,641 hours, and dividing by 11. These calculations lower hours worked per worker by 5.73 hours per year between 1913 and 1924.

Hours worked are constructed for the rest of the sample by following Cole and Ohanian (2002a). They assume a constant hours worked growth rate between 1924 and 1937.[12] Since dividing the difference between the 1937 aggregate hours worked observation of 2,293 and the 1924 aggregate hours worked observation of 2,219 by 13 is 5.69 hours, we apply a constant annual increase of 5.69 hours worked per worker to generate hours worked per worker observations from 1925 to 1938.

Two final calculations are needed to construct an uninterrupted per capita hours worked series from 1913 to 1938. The annual total hours worked per worker series is multiplied by the number of UK employed civilians plus military personnel, as reported in Feinstein (1972, T126). The last step divides this aggregate hours worked series by total population, from Feinstein (1972, T121), to produce uninterrupted per capita hours worked.[13] This is our preferred per capita hours worked series, which is labeled h_t in table 1.

We also construct an alternative per capita hours worked series to gauge the robustness of our preferred h_t. This alternative uses two indices of "normal weekly hours of manual workers in 69 principal industries and services" recovered from the Ministry of Labour *Gazette* (September 1957, pp. 330–331).[14] The Ministry of Labour *Gazette* reports an index of 'normal weekly hours' for an annual 1920–1933 sample that has a base year of 1924 (equal to 100) and another index with a base year of 1939 that runs from 1934 to 1947. We multiply the former series by the 1924 observation of aggregate hours worked found in Matthews, Feinstein, and Odling-Smee (1982). This process is repeated by applying their 1937 observation of aggregate hours worked to the second index from 1934 to 1938 making an adjustment for its 1939 base year. The series created by these two operations are spliced together to form a 1920-1938 sample of hours worked per week. The alternative per capita hours worked series for this period is generated by multiplying by UK employment and dividing by UK population. Prior to 1920, our preferred and alternative per capita hours worked observations are identical. The alternative per capita hours worked series is denoted $h_{Alt,t}$.

Table 1 shows that h_t and $h_{Alt,t}$ are remarkably similar after 1919. Our preferred per capita hours worked series is greater than $h_{alt,t}$ except in 1926, 1927, and 1934–1936. Further, differences

[12] The website http://www.greatdepressionsbook.com/datasets/UKData.xls links to the Cole and Ohanian (2002a) data set.

[13] Appendix A1 gives more details about UK civilian employment, military employment, and population from 1913 to 1938, which also are listed in table A1.

[14] The Ministry of Labour *Gazette* defines 'normal weekly hours' as falling under working conditions established by contract, legislation, or custom rather than actual hours worked per week; see McCormick (1959). Combining aggregate hours worked with the indices of 'normal weekly hours of manual workers' assumes that the notional hours worked behavior of these workers is a reasonable proxy for actual hours worked by UK workers not employed in the "69 principal industries and services" during the 1920s and 1930s. If this assumption is invalid, measurement error will be induced in the alternative per capita hours worked series.

in h_t and $h_{alt,t}$ are small. The largest discrepancy occurs in 1932 and is about 14 hours. These series indicate that the UK labor market was weak in 1921 and 1922. Subsequently, h_t and $h_{Alt,t}$ expand slowly for the rest of the 1920s, fall in 1930 and 1931, and recover from 1933 through 1937. It is only in 1938 that the paths of h_t and $h_{Alt,t}$ diverge.

Our uninterrupted h_t and $h_{Alt,t}$ series suggest a puzzle for an extant explanation of the interwar UK labor market. Table 1 shows h_t dropped by more than 16 percent between 1918 and 1919, increased by 1.8 percent in 1920, only to fall by 13.6 percent in 1921.[15] The puzzle is that Benjamin and Kochin (1979) and Cole and Ohanian (2002a) argue that more generous unemployment benefits beginning in 1920 explain much of the increase in UK unemployment during the 1920s.

2.3 Unit Root Tests and Sample Statistics: 1916–1938

Table 3 contains sample statistics of $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ on the 1916–1938 sample. Figure 1 shows that during this period $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ appear to display substantial persistence, but $\tau_{K,t}$ exhibits much greater volatility than $\tau_{N,t}$ and $\tau_{C,t}$. Before reviewing the sample statistics, we test whether the average tax rates are stationary in levels or persistent enough to justify applying the first difference operator.

We report unit root tests to assess the role that persistence has in average tax rate dynamics. The unit root tests are based on first-order autoregressions, AR(1)s. Table 2 contains ordinary least squares (OLS) estimates of the AR(1), $\tau_{i,t} = \alpha_{\tau_i} + \delta_{\tau_i}\tau_{i,t-1} + \xi_{\tau_i,t}$, for $i = K, N, C$, where $\xi_{\tau_i,t}$ is a mean zero, homoscedastic forecast innovation. The AR1 coefficient δ_{τ_i} measures persistence. Volatility is identified with the standard deviation of $\xi_{\tau_i,t}$, σ_{ξ,τ_i}, which is conditional on the AR(1) model.

The estimated AR(1)s yield a conditional volatility ranking of the average tax rates that reinforces a message of figure 1. The volatility of $\tau_{K,t}$ dominates that of $\tau_{N,t}$, and $\tau_{C,t}$. Table 2 includes an estimate of the standard deviation of $\xi_{\tau_K,t}$, $\widehat{\sigma}_{\xi,\tau_K}$ that is more than four times larger than $\widehat{\sigma}_{\xi,\tau_N}$ and seven times larger than $\widehat{\sigma}_{\xi,\tau_C}$.

Estimates of δ_{τ_i} are more difficult to interpret. One issue is that AR coefficients are biased downward in the presence of a unit root. An implication is that δ_{τ_i} has the nonstandard Dickey-Fuller (DF) distribution; see MacKinnon (1996). We garner evidence about the unit root hypothesis for $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ with the DF t-ratio and the Andrews and Chen (1994) approximate median-unbiased estimate of the AR1 coefficient, δ_{MU,τ_i}. These statistics appear at the bottom of table 2.

The null of the DF t-ratio is a unit root, $\delta_{\tau_i} = 1$. The alternative is that τ_i is stationary, $\left|\delta_{\tau_i}\right| < 1$.

[15]The alternative per capita hours worked measure was 1.2 percent higher in 1920 and in 1921 also declined by 13.6 percent.

We obtain finite-sample 1, 5, and 10 percent critical values of −3.75, −3.00, and −2.64 using software described in MacKinnon (1996).[16] Against these critical values, a unit root cannot be rejected for $\tau_{K,t}$ or $\tau_{C,t}$ at standard significance levels. The DF t-ratio of δ_{τ_N} is −3.81, which rejects the unit root null at the 1 percent level. We infer from these tests that $\Delta\tau_{K,t}$, $\tau_{N,t}$, and $\Delta\tau_{C,t}$ are stationary.

We report Andrews and Chen (1994) approximate median-unbiased estimates of the AR1 coefficient, $\hat{\hat{\delta}}_{MU,\tau_i}$, to measure the persistence of $\tau_{K,t}$ and $\tau_{C,t}$. With $\hat{\hat{\delta}}_{MU,\tau_C} = 1.02$, persistence in $\tau_{C,t}$ almost matches the unit root null. The response of $\tau_{C,t}$ is permanent (*i.e.*, never decays) to an own shock $\xi_{\tau_C,t}$ at this point estimate. The estimate $\hat{\hat{\delta}}_{MU,\tau_K} = 0.85$ indicates that $\tau_{K,t}$ is persistent, but that its response to an own shock $\xi_{\tau_K,t}$ has finite duration with a half-life of about 4 years. However, $T = 23$ years is a short annual sample that points to uncertainty surrounding $\hat{\hat{\delta}}_{MU,\tau_K}$ and $\hat{\hat{\delta}}_{MU,\tau_C}$. The last row of table 3 presents 90 percent confidence intervals that contain the unit root null for $\tau_{K,t}$, $\left[0.55,\ 1.09\right]$, and for $\tau_{C,t}$, $\left[0.74,\ 1.12\right]$. These 90 percent confidence intervals yield additional evidence that $\tau_{K,t}$ and $\tau_{C,t}$ are observationally equivalent to unit root processes on the McKenna rule regime of 1916 to 1938. Nonetheless, the lower end of these confidence intervals include values that signal less persistence in $\tau_{K,t}$ and $\tau_{C,t}$.

Tax rate persistence is used to evaluate tax rate policy by Bizer and Durlauf (1990), Hess (1993), and Scott (2007), among others. Their motivation is the tax smoothing model, which predicts optimal policy and requires tax rates to evolve as random walks. The random walk tax rate result depends on the tax smoothing model having incomplete markets (*i.e.*, the government cannot issue a complete set of Arrow-Debreu securities). Aiyagari, Marcet, Sargent, and Seppälä (2002) contrast the random walk in tax rates under incomplete markets to the Ramsey tax problem faced by the social planner of a complete markets economy that is studied by Lucas and Stokey (1983). In this case, the solution of the Ramsey problem yields stationary tax rates.

Scott (2007) extends these results by constructing tax rate regressions that respond only to macro variables from a complete markets dynamic stochastic general equilibrium (DSGE) model. When the DSGE model is restricted to having incomplete markets, the tax rate regression includes a lag of the tax rate with a unit coefficient.[17] The lesson of Aiyagari, Marcet, Sargent, and Seppälä (2002) and Scott (2007) is that there are limits to the inference that can be extracted from unit root tests of $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$. These tests are unable to disentangle the role of market complete or incompleteness

[16] The software is found at http://www.econ.queensu.ca/faculty/mackinnon/numdist/.

[17] Scott (2007) reports that OECD labor income tax rates are best described as approximating unit roots on a post-World War II sample of OECD economies.

from that of deviations from optimality in generating tax rate dynamics.

The unit root tests, together with figures 1 and 2, are useful for understanding a key argument of Nason and Vahey (2007). They show that the McKenna rule committed the UK to a state-contingent debt retirement path that forced a tax rate to adjust to close the government's budget constraint. Figures 1 and 2 reveal that the average capital income tax rate has greater volatility and is at a higher level after the 1920s than either the average labor income or the consumption tax rates. The average capital income tax rate is also more (as) persistent (as) than the average labor income (consumption) tax rate, according to the unit root tests. This evidence suggests that the UK relied on the capital income tax rate to be the buffer that was adjusted to meet the commitments of the McKenna rule.

This section closes by reviewing sample statistics of $\Delta\tau_{K,t}$, $\tau_{N,t}$, $\Delta\tau_{C,t}$; the growth rate of our preferred per capita hours worked series $\Delta \ln h_t$; and the growth rate of the alternative measure $\Delta \ln h_{Alt,t}$. We report sample statistics of $\Delta \ln h_t$ and $\Delta \ln h_{Alt,t}$ rather than levels (or log levels) because these series contain trends by construction. Table 3 lists the sample mean $\overline{X}$, standard deviation $\widehat{\sigma}_X$, maximum X_{Max}, minimum X_{Min}, and first-order autocorrelation coefficient $\widehat{\rho}_X(1)$, for $X = \Delta\tau_K$, τ_N, $\Delta\tau_C$, $\Delta \ln h$, and $\Delta \ln h_{Alt,t}$ on the 1916–1918 sample. Figure 2 plots $\Delta\tau_K$, $\Delta\tau_C$, $\Delta \ln h_t$, and $\Delta \ln h_{Alt,t}$ with a solid (red) line, dotted (brown) line, dot-dash (green) line, and solid (purple) line with circles, respectively, from 1914 to 1938.

There are important differences across the sample statistics of $\tau_{N,t}$ compared with those of $\Delta\tau_{K,t}$ and $\Delta\tau_{C,t}$ in table 3. On average $\tau_{N,t}$ is about 10 percent, which is large relative to $\widehat{\sigma}_{\tau_N} = 1.3$. This is not true for $\overline{\Delta\tau_K}/\widehat{\sigma}_{\Delta\tau_K}$ and $\overline{\Delta\tau_C}/\widehat{\sigma}_{\Delta\tau_C}$.[18] There is positive serial correlation in $\tau_{N,t}$, but $\widehat{\rho}_{\tau_N}(1) =$ 0.65 indicates rapid decay in less than two years. Only weak positive first-order serial correlation arises in $\Delta\tau_{K,t}$ and $\Delta\tau_{C,t}$. Finally, the row labeled $\widehat{\sigma}_X$ reveals that $\Delta\tau_K$ is more volatile than τ_N or $\Delta\tau_C$.[19]

Table 3 also contains sample statistics of $\Delta \ln h_t$. These statistics reveal $\Delta \ln h_t$ to be volatile and approximately serially uncorrelated. The fifth column of table 3 shows that relative to (the absolute value of) $\overline{\Delta \ln h}$, $\widehat{\sigma}_{\Delta \ln h}$ is about eight times larger, $\Delta \ln h_{Max}$ equals 3 percent (in 1937), $\Delta \ln h_{Min} =$ -16.5 percent (in 1919), and $\widehat{\rho}_{\Delta \ln h}(1) = -0.05$. These observations are bolstered by the plot of $\Delta \ln h_t$ in figure 2. However, interpreting the sample statistics of $\Delta \ln h_t$ require caution because trends and structural breaks are built into our preferred measure of per capita hours worked.

The statistics reported in table 3 are useful for examining the robustness of h_t to the assump-

[18]Sample means of $[\tau_{K,t}\ \ \tau_{C,t}] = [0.162\ \ 0.079]$. The associated standard deviations are 0.069 and 0.015.

[19]Tables A2 and A3 show that a drop in volatility is the biggest impact of moving from the McKenna rule sample to the interwar 1920–1938 and 1925–1938 samples.

tion used in its construction with $h_{Alt,t}$. The far right column of table 3 shows that $\Delta \ln h_{Alt,t}$ yields sample statistics that are about equal to those of $\Delta \ln h_t$. Plots of $\Delta \ln h_t$ and $\Delta \ln h_{Alt,t}$, depicted in figure 2, support the notion that the moments of these are nearly identical. The only notable difference is that $\Delta \ln h_{Alt,t}$ has a maximum growth rate of 5.5 percent (in 1934), which is almost twice as large as that of $\Delta \ln h_{Max}$ (in 1937).[20]

3. Applications

This section contains two applications. The first is a growth accounting exercise that exploits h_t to produce an uninterrupted TFP residual from 1916 to 1938. Next, we add combinations of $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ to the Benjamin and Kochin (1979) regression to conduct a Bayesian evaluation of the hypothesis that increased unemployment benefits drove the UK interwar unemployment rate higher.

3.1 World War I and Interwar UK Growth Accounting

The growth accounting exercise decomposes output growth into contributions made by capital, labor, and TFP conditional on a production function. We adopt the constant return to scale (CRS) production technology

$$Y_t = K_t^{\theta}[Z_t N_t]^{(1-\theta)}, \quad 0 < \theta < 1, \tag{1}$$

where Y_t, K_t, Z_t, and N_t denote output, the capital stock, labor-augmenting TFP, and labor input, respectively. Labor input equals total hours worked, $N_t = E_t \times h_t$, where E_t is the employment rate. We set capital's share, θ, at 0.35. The CRS production technology (1) is standard in macroeconomics. For example, Cho and Cooley (1994) use a similar production function to study the roles that adjustment along the extensive margin, E_t, and the intensive margin, h_t, play in aggregate fluctuations.[21]

The growth accounting exercise requires data on Y_t, K_t, E_t, and h_t to compute TFP for the UK from 1916 to 1938. We obtain UK output and capital from Feinstein (1972) and Mitchell (1988). Section 2.2 discusses the UK employment and population data needed to calculate E_t as well as construction of h_t. We measure Y_t and K_t per capita in constant 1913 pounds. The appendix summarizes the data, which appears in table A4. The TFP residual is computed by applying the log operator to the production function (1) and rearranging terms to obtain $\ln Z_t$ and its growth rate, $\gamma_{Z,t}$ (= $\ln Z_t - \ln Z_{t-1}$).

[20] The similarity in these basic sample statistics is carried over to the interwar 1920–1938 and shorter interwar 1925–1938 samples as shown in tables A1 and A2 of the appendix.

[21] Cole and Ohanian (2002a) employ the CRS technology $[h_t K_t]^{\theta}[Z_t N_t]^{(1-\theta)} = K_t^{\theta}[Z_t E_t]^{(1-\theta)} h_t$ in a growth accounting exercise. Their technology equates the workweeks of E_t and K_t. The production function (1) holds the capital utilization rate fixed which avoid this restriction.

The results of the growth accounting exercise are found in table 4. This table contains sample statistics for the 1916–1938, 1920–1938, and 1925–1938 samples in its top, middle, and bottom panels. We study these samples to gauge the robustness of the growth accounting exercise across the McKenna rule regime and interwar samples. The 1925–1938 sample is included to examine the impact of excluding the 'transwar' period on interwar UK economic outcomes. On these samples, table 4 reports the sample mean $\overline{\gamma}_X$, standard deviation $\widehat{\sigma}_{\gamma_X}$, maximum $\gamma_{Max,X}$, minimum $\gamma_{Min,X}$, and first-order autocorrelation coefficient $\widehat{\rho}_{\gamma_X}(1)$ of the growth rates $\gamma_{X,t}$, $X_t = Y_t,\ K_t,\ N_t$, and Z_t.

The sample means of $\overline{\gamma}_Z$ and $\overline{\gamma}_K$ exhibit little change across the three samples. Table 4 shows that $\overline{\gamma}_Z$ is about 1 percent no matter the sample. Likewise, $\overline{\gamma}_K$ changes by only 0.2 percent from the longest sample to the two interwar samples.

There are larger shifts in $\overline{\gamma}_Y$ and $\overline{\gamma}_N$ moving from the McKenna rule regime to the interwar samples. Output growth increases from 0.6 to 1 percent by ignoring the 1916–1919 observations and rises to 1.7 percent after dropping the 'transwar' period. Much of the increase in $\overline{\gamma}_Y$ is generated by $\overline{\gamma}_N$ moving from negative, to zero, to about 1.4 percent as the World War I and early interwar years are eliminated from the samples.

Table 4 shows there is little change in volatility, $\widehat{\sigma}_\gamma$, and persistence, $\widehat{\rho}_\gamma(1)$, of $\overline{\gamma}_Y$, $\overline{\gamma}_K$, $\overline{\gamma}_N$, and $\overline{\gamma}_Z$ on the 1916–1938 and 1920–1938 samples. Across these samples, $\widehat{\sigma}_{\gamma_N}$ and $\widehat{\sigma}_{\gamma_Z}$ are close and about 50 percent larger than $\widehat{\sigma}_{\gamma_Y}$ and $\widehat{\sigma}_{\gamma_K}$. Persistence is similar on the McKenna rule and 1920-1938 samples with small positive $\widehat{\rho}_{\gamma,Y}(1)$, slightly negative $\widehat{\rho}_{\gamma,K}(1)$ and $\widehat{\rho}_{\gamma,Z}(1)$, and near zero $\widehat{\rho}_{\gamma,N}(1)$.

The 1925–1938 sample sees some shifts in $\widehat{\sigma}_\gamma$ and $\widehat{\rho}_\gamma(1)$. The bottom panel of table 4 contains smaller $\widehat{\sigma}_\gamma$ for output, capital, labor, and TFP compared with those from the longer samples. The first-order serial correlation coefficient, $\widehat{\rho}_{\gamma_X}(1)$, of output, capital, and labor growth switch signs on the 1925–1938 sample compared to longer samples. This statistic exhibits small negative $\widehat{\rho}_{\gamma_X}(1)$ for output growth, while the same statistics for γ_K, and γ_N are positive. TFP growth, γ_Z, becomes more negatively serially correlated on the 1925–1938 sample.

Figure 3 plots the results of the growth accounting exercise for the UK from 1916 to 1938. The top row of windows in figure 3 gives two perspectives on movements in Y_t, K_t, and N_t. Growth rates appear in the top left window of figure 3. We report a low frequency or trend measure in the top right window, which is $\Gamma_{X,t} = \ln X_t - \ln X_{1916}$, $X_t = Y_t, K_t, N_t$, and $t = 1916, \ldots, 1938$. The top row of windows of figure 3 depict these growth rates of Y_t, K_t, and N_t plots with (blue) solid, (red) dashed, and (green) dotted lines, respectively.

The volatility message of table 4 is reinforced by the plots of $\gamma_{Y,t}$, $\gamma_{K,t}$, and $\gamma_{N,t}$ in the top left window of figure 3. These plots are visual evidence that $\gamma_{Y,t}$, $\gamma_{K,t}$, and $\gamma_{N,t}$ are more volatile from 1916 to 1922 than during the 1923–1938 period.

The top right window of figure 3 focuses attention on lower frequency movements in Y_t, K_t, and N_t. Lower frequency fluctuations appear as peaks and troughs in long-run growth paths. For example, plots of $\Gamma_{Y,t}$ and $\Gamma_{N,t}$ peak in 1918 followed by a steep drop. The cumulative loss in Y_t is over 22 percent by 1921 and for N_t it is more than 40 percent by 1922. The path $\Gamma_{K,t}$ takes sees it rise at first during World War I and then fall before peaking with a cumulative gain of almost 13 percent in 1920. From the mid-1920s to 1938, there is growth in $\Gamma_{Y,t}$, $\Gamma_{K,t}$, and $\Gamma_{N,t}$ with the late 1920s and early 1930s being the only major exception.

The growth and trend growth rates of TFP are displayed in the bottom row of windows in figure 3. These plots reveal that the UK had a productivity boom toward the end of World War I. However, the bottom left window of figure 3 shows $\gamma_{Z,1919} = -0.5$ percent and $\gamma_{Z,1920} = -20.1$ percent, which indicates that the fall in UK TFP subsequent to World War I turned into a collapse by 1920. There is an immediate recovery in TFP the next year, $\gamma_{Z,1921} = 18.9$ percent, but there are five years in which $\gamma_{Z,t}$ is negative, from 1925 to 1938 (*i.e.*, 1927, 1932, 1934, 1937, and 1938), and that average -1.5 percent. Nonetheless, the average of $\gamma_{Z,t}$ is 3.3 percent after 1925, given $\gamma_{Z,t} > 0$. This helps to explain the economic recovery of the mid-1920s and the reduced volatility of $\sigma_{\gamma_Z} = 3.4$ percent on the 1925–1938 sample compared with σ_{γ_Z} of 6.8 percent and 7.4 percent on the 1920–1938 and 1916–1938 samples.

The bottom right window of figure 3 maps $\gamma_{Z,t}$ into $\Gamma_{Z,t}$. This trend measure of TFP appears in the bottom right window of figure 3. In this window, $\Gamma_{Z,t}$ depicts a peak in TFP during World War I, its steep post-war decline, and a recovery in TFP that levels off by 1925. Similar evidence is reported by Bienefeld (1972); Matthews, Feinstein, and Odling-Smee (1982); and Broadberry (1986, 1990). Nonetheless, we close this section by noting that, without the uninterrupted hours worked series h_t, it is not possible to observe that the collapse in TFP from 1919 to 1921 was wedged between a small boom during World War I and a recovery beginning in 1922.[22]

3.2 The Benjamin-Kochin Regression Revisited

Benjamin and Kochin (1979, 1982) contend that generous unemployment insurance benefits produced a higher UK unemployment rate, UR_t, in the interwar period. Their analysis relies on an ordi-

[22] Table A3 reports moments of a growth accounting exercise that relies on $h_{Alt,t}$. This growth accounting exercise produces TFP growth and its accumulated growth path displayed in figure A1 from 1916 to 1938. Given $\Delta \ln h_t$ and $\Delta \ln h_{Alt,t}$ yield similar moments, it is not surprising that replacing h_t with $h_{Alt,t}$ yields similar predictions for UK TFP from 1916 to 1938.

nary least squares (OLS) regression of the UR_t on the ratio of benefits to wages, the replacement ratio RR_t, detrended log real net national product, y_t, and a constant. The appendix discusses construction of UR_t, RR_t, and y_t. Table A5 lists the series.

We refer to regressing the UR_t on a constant, the RR_t, and y_t as the BK regression. The BK hypothesis is that there is a positive, economically large, and statistically significant response of UR_t to RR_t. On the McKenna rule sample of 1916–1938, the estimated BK regression is

$$UR_t = \underset{(1.77)}{1.12} + \underset{(4.04)}{23.55}\, RR_t - \underset{(6.44)}{26.83}\, y_t, \tag{2}$$

with standard errors in parentheses, and the standard deviation of the regression residuals is 3.05. There is solace for Benjamin and Kochin (1979, 1982) in these estimates because the elasticity of UR_t with respect to RR_t is 0.90 at the sample means.

This section studies the robustness of the BK regression and hypothesis with Bayesian model averaging (BMA) methods. The robustness issues are addressed by modifying the BK regression to include different combinations of $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ on the McKenna rule sample of 1916 to 1938. Our motivation is that DSGE models with capital income, labor income, and consumption taxes predict that these fiscal instruments distort labor supply-demand decisions as well as affecting choices over consumption and saving. According to Braun (1994) and McGrattan (1994), these distortions have an impact on business cycle fluctuations. This suggests adding $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ to the BK regression to assess the impact on the UK unemployment rate from 1916 to 1938. Thus, we also exploit $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ to study the impact of model uncertainty over which variables should be explanatory variables for the UK unemployment rate.

There is a tradition that views the BK regression as misspecified.[23] However, misspecification of the BK regression is not relevant for our Bayesian model averaging (BMA) exercise analysis. The BMA exercise provides evidence about model uncertainty over the BK regression and several alternatives conditional on the data rather than which regression specification is or is not correct.

We employ BMA to study the uncertainty of the BK regression and the impact, if any, on the BK hypothesis. Uncertainty about the BK regression is assessed by adding $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ one at a

[23] The structural interpretation BK give to their regression has generated much debate. Critiques of the BK regression focus on: (a) measurement of aggregate UK unemployment and the extent of unemployment insurance coverage across industries and trades classification [Cross (1982); Metcalf, Nickell, and Floros (1982); Eichengreen (1987); Hatton and Bailey (2002); and Hatton (2005)]; (b) long-term change in UK industrial structure [Collins (1982), Garside (1990), Loungani (1991), and Cole and Ohanian (2002a)]; and (c) small sample issues [Cross (1982) and Ormerod and Worswick (1982)]. Benjamin and Kochin (1982) reply to these critiques.

time and in various groups to the BK regression. The most general alternative to the BK regression is

$$(3) \qquad UR_t = \beta_0 + \beta_{RR}RR_t + \beta_y y_t + \beta_{\tau_K}\tau_{K,t} + \beta_{\tau_N}\tau_{N,t} + \beta_{\tau_C}\tau_{C,t} + e_t,$$

where e_t is a mean zero error term with homoscedastic variance, σ_e^2. Figure 4 plots the right- and left-hand side variables of regression (3) from 1916 to 1938. The variables UR_t, RR_t, y_t, $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ are denoted as a solid line with diamonds, a solid line with stars, a solid line with squares, a plain solid line, a dashed line, and a dotted line, respectively. A striking feature of figure 4 is that the paths of RR_t and $\tau_{K,t}$ appear to move together through the sample.

Regression (3) is one of seven models we estimate. The remaining six regressions are formed by estimating three models with two of the three tax rates and three models with only one of the three tax rates. We call the seven models modified BK regressions and label these $M_1, \ldots, M_7$, where regression (3) is M_7. The BMA exercise adds seven more regressions that are identical to $M_1, \ldots, M_7$ except that β_{RR} = 0. These regressions are labeled $M_{1,\mathcal{R}}, \ldots, M_{7,\mathcal{R}}$. The model space $\mathcal{M} = \left\{M_1, M_{1,\mathcal{R}}, \ldots, M_7, M_{7,\mathcal{R}}\right\}$ contains the 14 regressions. Levels regressions appear in $\mathcal{M}$ to be consistent with Benjamin and Kochin (1979).

Table 5 reports OLS estimates of $\mathcal{M}$ on the 1916–1938 sample. These estimates suggest uncertainty about the regressions in $\mathcal{M}$. However, it should not be a surprise that M_7 and $M_{7,\mathcal{R}}$ produce the smallest (and nearly identical) estimates of σ_e.

Uncertainty about the regression specifications is tied to fragility of the BK hypothesis, β_{RR} = 0 across $M_1, \ldots, M_7$. There are three modified BK regressions, M_2, M_3, and M_6, that produce $\hat{\beta}_{RR}$ > 0 with $t-$ratios greater than two. These modified BK regressions include $\tau_{N,t}$ and $\tau_{C,t}$, but $\tau_{K,t}$ is absent. There is less support for the BK hypothesis when $\tau_{K,t}$ appears in the modified BK regressions M_1, M_4, M_5, and M_7. These modified BK regressions yield $\hat{\beta}_{RR}$ that are small compared with $\hat{\beta}_{RR}$ = 23.5 reported by the estimated BK regression (2). Thus, the BK hypothesis appears to be compromised by adding $\tau_{K,t}$ to the BK regression.[24]

The modified BK regressions in the model space $\mathcal{M}$ are a platform for gauging the vulnerability of the BK hypothesis. Although standard $t-$ratios might suggest that adding $\tau_{K,t}$ negates the BK hypothesis, we do not take that position. Instead, we view the OLS estimates and standard errors of table 5 as evidence that there is substantial uncertainty across the 14 regressions $\left\{M_1, M_{1,\mathcal{R}}, \ldots, M_7, M_{7,\mathcal{R}}\right\}$.

[24]Nason and Vahey (2006) report Bayesian Monte Carlo Markov chain estimates for the BK regression with $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$ and obtain qualitatively similar results for the BK hypothesis.

By ignoring this uncertainty, a researcher may overstate the precision of estimated coefficients and place insufficient concern on the fragility of the hypothesis under review.

The goal of the BMA exercise is to compute the posterior model probability that RR_t should be excluded from the modified BK regressions $M_1, \ldots, M_7$. The BMA procedure exploits rules of conditional probability to compute this probability for inferences about the parameter of interest, β_{RR}. Our BMA application follows Koop (2003) and an example in Garratt, Koop, and Vahey (2008). Define $\Pr\left(M_i \middle| \mathcal{D}\right)$ for the BK regression, where $\mathcal{D} = \left[UR_t \;\; 1 \;\; RR_t \;\; y_t \;\; \tau_{K,t} \;\; \tau_{N,t} \;\; \tau_{C,t}\right]$ is the data vector. The posterior model probability is found using Bayes rule

$$\Pr\left(M_i \middle| \mathcal{D}\right) \propto \Pr\left(\mathcal{D} \middle| M_i\right) \Pr\left(M_i\right),$$

where $\Pr\left(\mathcal{D} \middle| M_i\right)$ is the marginal likelihood and the prior model probability is $\Pr\left(M_i\right)$. Our prior is noninformative such that each model receives equal weight, $\Pr\left(M_i\right) = 7^{-1}$. The post-data probability of M_i is approximated with the Schwarz or Bayesian information criterion (BIC). This approximation is

(4) $$\Pr\left(M_i \middle| \mathcal{D}\right) = \frac{\text{BIC}_i}{\sum_{i=1}^{7} \text{BIC}_i},$$

where $\text{BIC}_i = \hat{\mathcal{L}}_i - 0.5 k_i \ln T$, $\hat{\mathcal{L}}_i$ is the log likelihood function computed at the maximum likelihood estimates (*i.e.*, OLS) of M_i, k_i is the number of parameters in M_i, and T (= 23) is the sample size.

Our interest is in the probability that the data support the restriction $\beta_{RR} = 0$, $\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}\right)$. The rules of conditional probability yield

(5) $$\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}\right) = \sum_{i=1}^{7} \Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}, M_i\right) \Pr\left(M_i \middle| \mathcal{D}\right),$$

where $\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}, M_i\right)$ is the probability that RR_t has no predictive content for UR_t conditional on $\mathcal{D}$ and M_i. The noninformative prior requires the probability that RR_t is excluded from or excluded in the elements of $\mathcal{M}$ to equal 0.5. The probability that RR_t has no predictive content for UR_t in M_i is

(6) $$\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}, M_i\right) = \frac{\exp\left(\text{BIC}_{i,\mathcal{R}}\right)}{\exp\left(\text{BIC}_{i,\mathcal{R}}\right) + \exp\left(\text{BIC}_i\right)}, \quad i = 1, \ldots, 7,$$

where $\text{BIC}_{i,\mathcal{R}}$ and BIC_i denote the BICs for the restricted $M_{i,\mathcal{R}}$ ($\beta_{RR,i} = 0$) and unrestricted M_i. Thus,

$\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}, M_i\right)$ relies on posterior model probabilities of the ith restricted and unrestricted modified BK regressions.

We assess the predictive content of RR_t using evidence from $\mathcal{M}$ given $\mathcal{D}$. This is the probability $\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}\right)$ of (5). It is computed using the conditional probability (6), weighted by the posterior probability of (4), summed from $i = 1, \ldots, 7$. Given the McKenna rule sample of 1916 to 1938, the $\Pr\left(\beta_{RR} = 0 \middle| \mathcal{D}\right) = 0.79$, while it is 0.67 on the interwar 1920–1938 sample. Thus, the probability that RR_t has predictive content for UR_t is 21 percent and 33 percent on the 1916–1938 and 1920–1938 samples, respectively. These probabilities are well short of the 99 percent significance claimed by Benjamin and Kochin (1979, 1982). We conclude there is little support for the BK hypothesis that the RR_t contributes to variation in UR_t based on uncertainty about the BK regression specification during the McKenna rule and interwar samples.

4. Conclusion

This paper fills in gaps in the World War I and interwar UK time series. We tabulate time series of ex post UK average capital income, labor income, and consumption tax rates and per capita hours worked from 1913 to 1938. Details about data sources and construction methods are discussed in the first part of the paper.

The rest of the paper displays some of the uses to which the UK average tax rates and per capita hours worked time series can be put. We test for a unit root in the average tax rates and report sample statistics of the average labor income tax rates, first differences of the average capital income and consumption tax rates, and the growth rates of our preferred and alternative per capita hours worked. The paper also reports growth accounting exercises for the UK on 1916–1938, 1920–1938, and 1925–1938 samples as well as Bayesian model averaging experiments to examine the robustness of the Benjamin and Kochin (1979) regression and hypothesis on 1916–1938 and 1920–38 samples.

The results point future research in several new directions. For example a unit root is rejected for the average labor income tax rate on the 1916–1938 sample, but not for the average capital income and consumption tax rates. Optimal tax theory predicts that the labor income tax rate is stationary when financial markets are complete, but not when financial markets are incomplete. Although Scott (2007) shows that the optimality of tax policy cannot be evaluated with unit root tests, it is the case that UK financial markets were far from complete during World War I and the interwar period. Further, Daunton (2002) argues that UK fiscal policy followed the McKenna rule dictum and relied on capital income taxation to achieve the goals of UK fiscal policy from 1916 to 1938. Nason and Vahey (2007) provide evidence that the McKenna rule had an adverse effect on the UK economy. This suggests there is a gap to be filled by research that uses the benchmark of optimal tax theory to assess the impact of the McKenna rule on the UK economy.

The UK growth accounting exercise finds that capital and total factor productivity growth supported positive average output growth in the face of negative average total hours worked growth during the McKenna rule sample of 1916 to 1938. These results are consistent with Cole and Ohanian (2002a) who report a growth accounting exercise that shows a drop in labor input growth that coincides with low average UK output growth during the interwar period. However these results also leave unexplained why capital grew during the interwar period, which contributed to output growth, when the McKenna rule regime aimed to tax capital heavily.

We also study the Benjamin and Kochin (1979) hypothesis that contends that the generosity of unemployment benefits spurred a rise in the unemployment rate in the UK during the interwar period. Bayesian model averaging is employed to examine the uncertainty of the Benjamin and Kochin hypothesis on the McKenna rule sample of 1916 to 1938 and the interwar 1920–1938 sample by adding various combinations of the average capital income, labor income, and consumption tax rates to the Benjamin and Kochin regression. The Bayesian model averaging experiments expose the lack of robustness in the Benjamin and Kochin hypothesis on the McKenna rule and interwar samples. Although questions about the high interwar UK unemployment rate have not been fully answered, Nason and Vahey (2007) suggest that the fiscal stringency of the McKenna rule may have been a contributing factor.

Our view is that the growth accounting exercise and applying Bayesian model averaging to the Benjamin and Kochin regression raise more questions about the impact of fiscal policy on the UK economy during World War I and the interwar period. Future analysis of these data using Keynesian and non-Keynesian theories and models will yield more insight into the UK economy from World War I through the interwar period. Although these questions are left for future research, Cole and Ohanian (2002a, 2002b) and Nason and Vahey (2007) are good starting points.

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Table 1: UK Per Capita Hours Worked and Average Tax Rates, 1913–1938

	$\tau_{K,t}$	$\tau_{N,t}$	$\tau_{C,t}$	$\tau_{EPD,t}$	h_t	$h_{Alt,t}$
1913	0.0538	0.0388	0.0444	–	1175.0249	1175.0249
1914	0.0601	0.0389	0.0434	–	1158.8584	1158.8584
1915	0.0510	0.0527	0.0529	–	1185.3950	1185.3950
1916	0.0390	0.0700	0.0577	0.1314	1195.8753	1195.8753
1917	0.0345	0.0982	0.0453	0.2185	1199.1299	1199.1299
1918	0.0304	0.0910	0.0469	0.2669	1205.3611	1205.3611
1919	0.0339	0.1106	0.0611	0.2557	1022.0481	1022.0481
1920	0.0934	0.0971	0.0665	0.2539	1040.8534	1033.9975
1921	0.2641	0.1069	0.0795	0.1527	908.6391	902.9199
1922	0.2263	0.1277	0.0862	0.0382	898.5255	895.8317
1923	0.2011	0.1139	0.0842	0.0309	903.2405	900.8096
1924	0.1756	0.1094	0.0750	0.0255	907.9546	907.6109
1925	0.1708	0.1058	0.0745	0.0172	917.7429	913.2181
1926	0.1884	0.0980	0.0764	0.0081	916.8186	920.9116
1927	0.1913	0.0882	0.0795	0.0013	942.7299	944.5279
1928	0.1794	0.0913	0.0815	–	944.5552	943.9537
1929	0.1774	0.0896	0.0796	–	958.5370	950.7702
1930	0.2179	0.0938	0.0783	–	939.0188	929.9814
1931	0.2286	0.1108	0.0820	–	915.0793	905.7857
1932	0.2491	0.1222	0.0945	–	916.5186	904.9300
1933	0.2295	0.1057	0.0936	–	933.8593	919.7395
1934	0.1696	0.0977	0.0960	–	960.0468	971.5686
1935	0.1748	0.0889	0.0948	–	975.4359	983.7007
1936	0.1505	0.0842	0.0971	–	1004.1981	1009.1812
1937	0.1423	0.0908	0.0963	–	1035.9207	1035.3738
1938	0.1604	0.0987	0.0945	–	1036.6234	1032.4780

The average capital income, labor income, consumption, and excess profits duty (EPD) tax rates are denoted $\tau_{K,t}$, $\tau_{N,t}$, $\tau_{C,t}$, and $\tau_{EPD,t}$, respectively. Per capita hours worked is represented by h_t and the alternative series $h_{Alt,t}$. The former series is computed by the authors as discussed in the text. The alternative per capita hours worked series, $h_{alt,t}$, is based on weekly hours indices from the Ministry of Labour Monthly *Gazette* (September 1957) on samples from 1920 to 1933 and 1934 to 1939 samples. The text also discusses the calculations used to generate $h_{Alt,t}$.

Table 2: Dickey-Fuller Regressions of UK Average Tax Rates, 1916–1938

DF: $\tau_{i,t} \;=\; \alpha_{\tau_i} \;+\; \delta_{\tau_i}\tau_{i,t-1} \;+\; \xi_{\tau_i,t}, \;\; i = K, N, C, \;\; T = 23.$

	$\tau_{K,t}$	$\tau_{N,t}$	$\tau_{C,t}$
$\hat{\alpha}$	0.040	0.049	0.011
	(0.021)	(0.013)	(0.006)
$\hat{\delta}$	0.774	0.516	0.887
	(0.115)	(0.127)	(0.079)
$\hat{\sigma}_{\xi}$	0.040	0.010	0.006
DF t-ratio	−1.970	−3.811	−1.430
$\hat{\delta}_{MU}$	0.849	-	1.022
	[0.553 1.088]	-	[0.737 1.123]

The regressions are estimated by ordinary least squares (OLS). OLS standard errors appear in parentheses. The DF t-ratio has MacKinnon (1996) finite-sample 1, 5, and 10 percent critical values of −3.753, −2.998, and −2.639, respectively. The brackets contain lower and upper values of 90 percent confidence intervals of the Andrews and Chen (1994) approximate median-unbiased estimates of the first-order autoregressive coefficient, $\hat{\delta}_{MU}$.

Table 3: Sample Statistics of UK Average Tax Rates and Per Capita Hours Worked, 1916–1938

	$\Delta\tau_K$	τ_N	$\Delta\tau_C$	$\Delta\ln h$	$\Delta\ln h_{Alt}$
$\overline{X}$	0.005	0.100	0.002	−0.006	−0.006
$\hat{\sigma}_X$	0.043	0.013	0.006	0.048	0.049
X_{Max}	0.171	0.128	0.014	0.031	0.055
X_{Min}	−0.060	0.070	−0.012	−0.165	−0.165
$\hat{\rho}_X(1)$	0.148	0.646	0.189	−0.051	−0.040

The sample mean, standard deviation, maximum, minimum, and first-order autocorrelation coefficient are denoted by $\overline{X}$, $\hat{\sigma}_X$, X_{Max}, X_{Min}, and $\hat{\rho}_X(1)$, respectively.

Table 4: UK World War I and Interwar Growth Accounting Summary Statistics

Sample		Y	K	N	Z
1916–1938					
	$\overline{\gamma}$	0.006	0.009	−0.006	0.010
	$\hat{\sigma}_\gamma$	0.046	0.047	0.076	0.068
	γ_{Max}	0.074	0.141	0.060	0.189
	γ_{Min}	−0.103	−0.115	−0.269	−0.201
	$\hat{\rho}_\gamma(1)$	0.220	−0.185	−0.034	−0.246
1920–1938					
	$\overline{\gamma}$	0.010	0.011	0.000	0.010
	$\hat{\sigma}_\gamma$	0.043	0.046	0.073	0.074
	γ_{Max}	0.074	0.141	0.060	0.189
	γ_{Min}	−0.093	−0.115	−0.269	−0.201
	$\hat{\rho}_\gamma(1)$	0.300	−0.233	−0.025	−0.245
1925–1938					
	$\overline{\gamma}$	0.017	0.012	0.016	0.004
	$\hat{\sigma}_\gamma$	0.036	0.020	0.036	0.034
	γ_{Max}	0.074	0.054	0.060	0.052
	γ_{Min}	−0.057	−0.013	−0.054	−0.063
	$\hat{\rho}_\gamma(1)$	−0.038	0.184	0.335	−0.373

The sample mean, standard deviation, maximum, minimum, and first-order autocorrelation coefficient of the growth rates are denoted by $\overline{\gamma}$, $\hat{\sigma}_\gamma$, γ_{Max}, γ_{Min}, and $\hat{\rho}_\gamma(1)$, respectively.

Table 5: Modified BK Regressions, 1916–1938

Dependent Variable: UK Unemployment Rate, UR_t

	$\widehat{\beta}_0$	$\widehat{\beta}_{RR}$	$\widehat{\beta}_{\mathcal{Y}}$	$\widehat{\beta}_{\tau_K}$	$\widehat{\beta}_{\tau_N}$	$\widehat{\beta}_{\tau_C}$	$\widehat{\sigma}_e$
M_1	−3.73	6.62	6.46	77.59	–	–	2.28
	(1.74)	(5.37)	(9.18)	(18.21)			
$M_{1,\mathcal{R}}$	−4.03	–	13.78	96.14	–	–	2.36
	(1.78)		(7.21)	(10.57)			
M_2	−12.28	26.70	−15.82	–	129.82	–	2.79
	(6.51)	(3.73)	(7.84)		(61.09)		
$M_{2,\mathcal{R}}$	4.91	–	−29.09	–	66.72	–	5.01
	(10.86)		(13.68)		(108.55)		
M_3	−6.06	14.35	−22.30	–	–	148.45	2.86
	(4.37)	(7.36)	(6.56)			(83.66)	
$M_{3,\mathcal{R}}$	−11.26	–	−19.17	–	–	288.22	3.09
	(3.73)		(6.86)			(46.46)	
M_4	−13.48	8.89	12.29	71.82	97.95	–	2.09
	(4.88)	(5.03)	(8.84)	(16.88)	(46.31)		
$M_{4,\mathcal{R}}$	−12.13	–	20.65	96.63	80.47	–	2.23
	(5.13)		(7.96)	(9.98)	(48.21)		
M_5	−9.60	−2.13	9.04	74.69	–	125.21	2.10
	(3.30)	(6.56)	(8.54)	(16.83)		(61.62)	
$M_{5,\mathcal{R}}$	−8.93	–	7.43	71.60	–	112.10	2.11
	(2.58)		(6.97)	(13.90)		(46.60)	
M_6	−17.71	16.58	−12.57	–	120.18	132.92	2.63
	(6.89)	(6.84)	(7.62)		(57.76)	(77.11)	
$M_{6,\mathcal{R}}$	−21.45	–	−10.83	–	98.22	293.31	2.94
	(7.52)		(8.50)		(63.91)	(44.36)	
M_7	−18.14	0.68	14.23	69.58	90.60	115.09	1.92
	(5.04)	(6.14)	(8.19)	(15.58)	(42.79)	(56.57)	
$M_{7,\mathcal{R}}$	−18.25	–	14.66	70.58	89.57	119.23	1.92
	(4.95)		(7.20)	(12.70)	(41.79)	(42.68)	

Mnemonics β_0, RR, $\mathcal{Y}$, $\widehat{\sigma}_e$, τ_K, τ_N, and τ_C denote the intercept, replacement ratio, linear detrended log net national product, standard deviation of regression residuals, and average capital income, labor income, and consumption tax rates, respectively. Models $M_1, \ldots, M_7$ ($M_{1,\mathcal{R}}, \ldots, M_{7,\mathcal{R}}$) are modified BK regressions that include different combinations of $\tau_{K,t}$, $\tau_{N,t}$, and $\tau_{C,t}$, and (exclude) RR_t. The regressions are estimated by OLS on the 1916–1938 sample, $T = 23$. Parentheses contain OLS standard errors.

Fig. 1: U.K. Average Tax Rates, 1913--1938

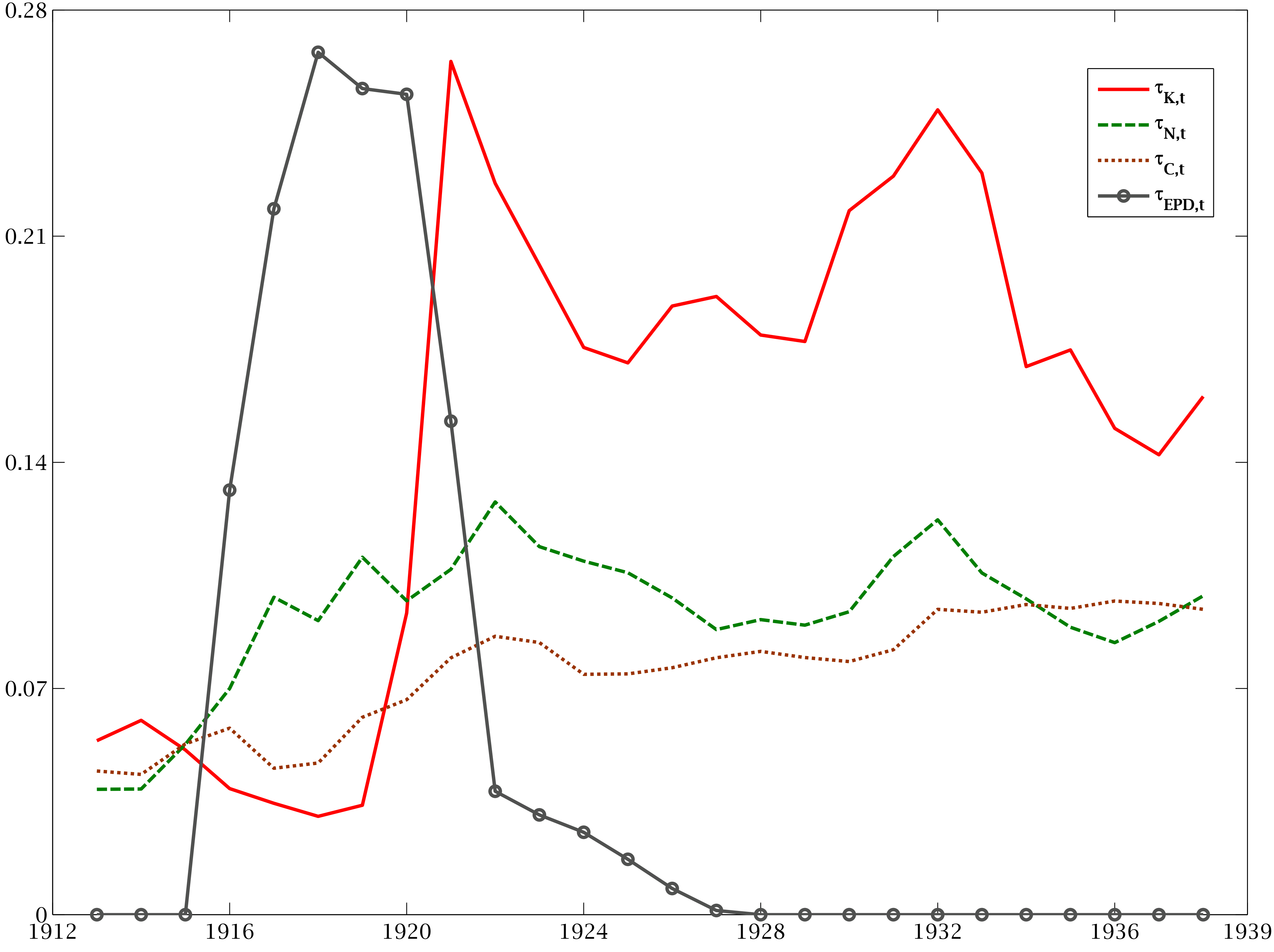


Fig. 2: Changes in Average Tax Rates and Growth Rate of Per Capita Hours Worked, 1914-1938

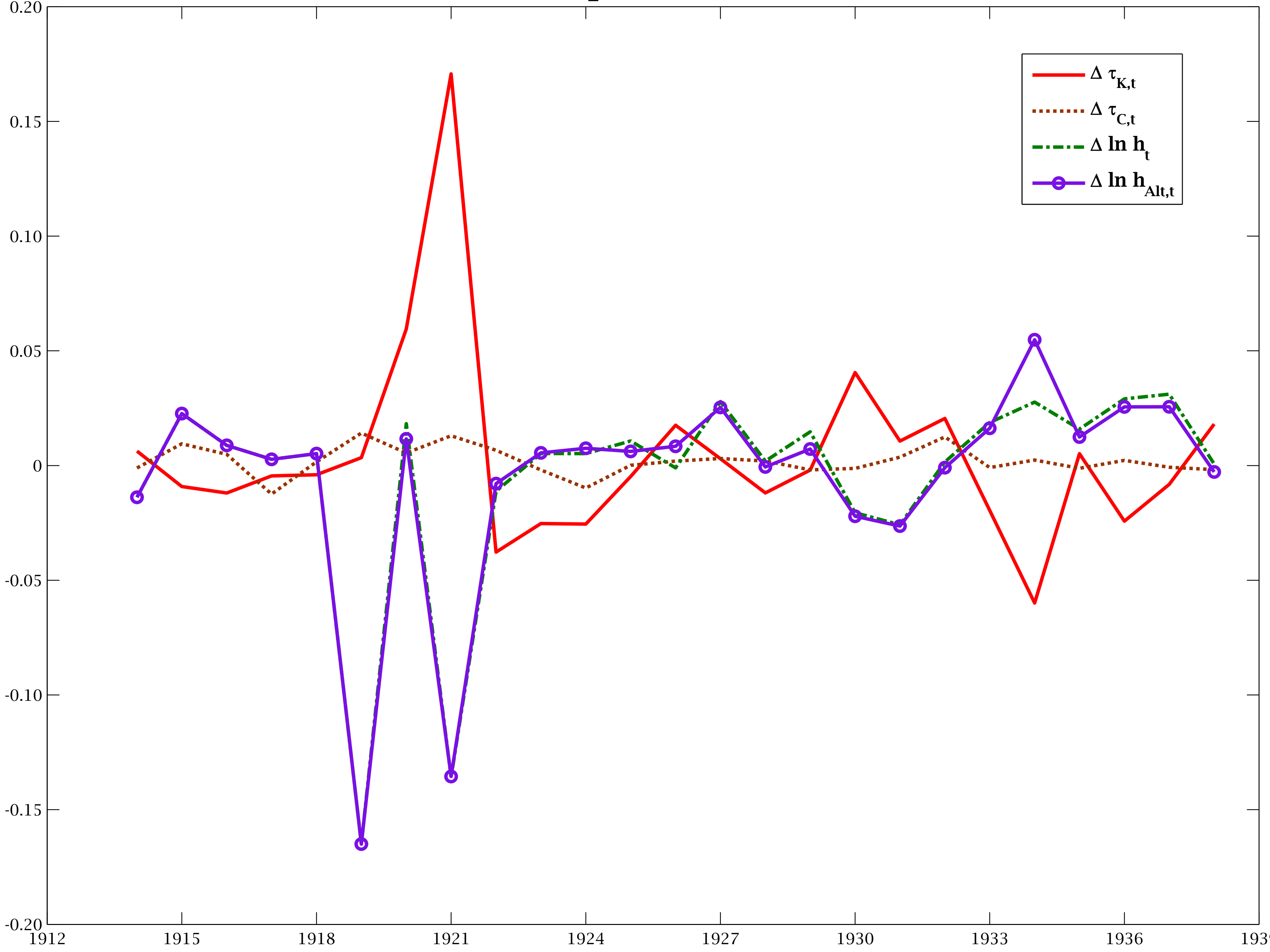


Fig. 3: U.K. WWI and Interwar Productivity Accounting, 1916-1938

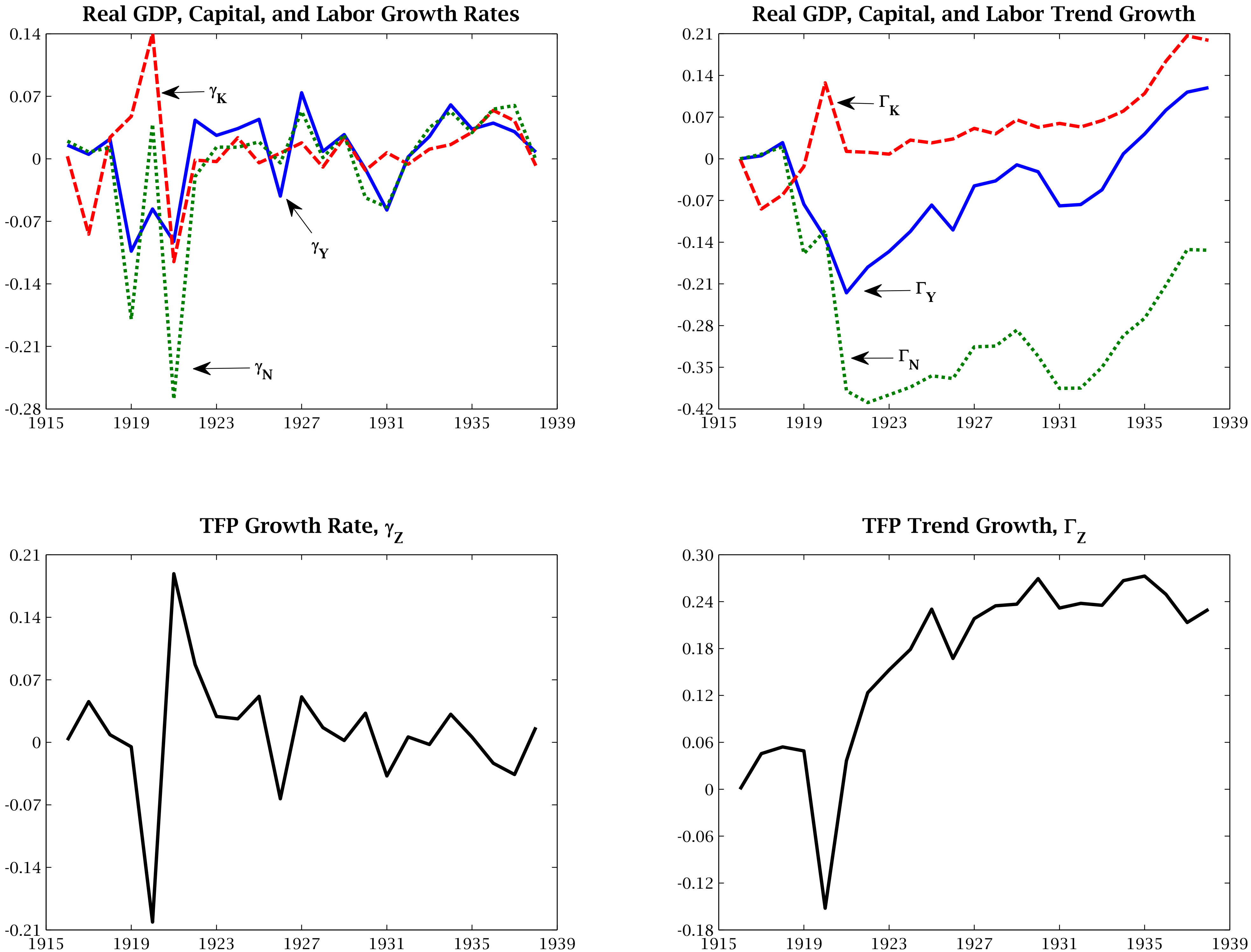
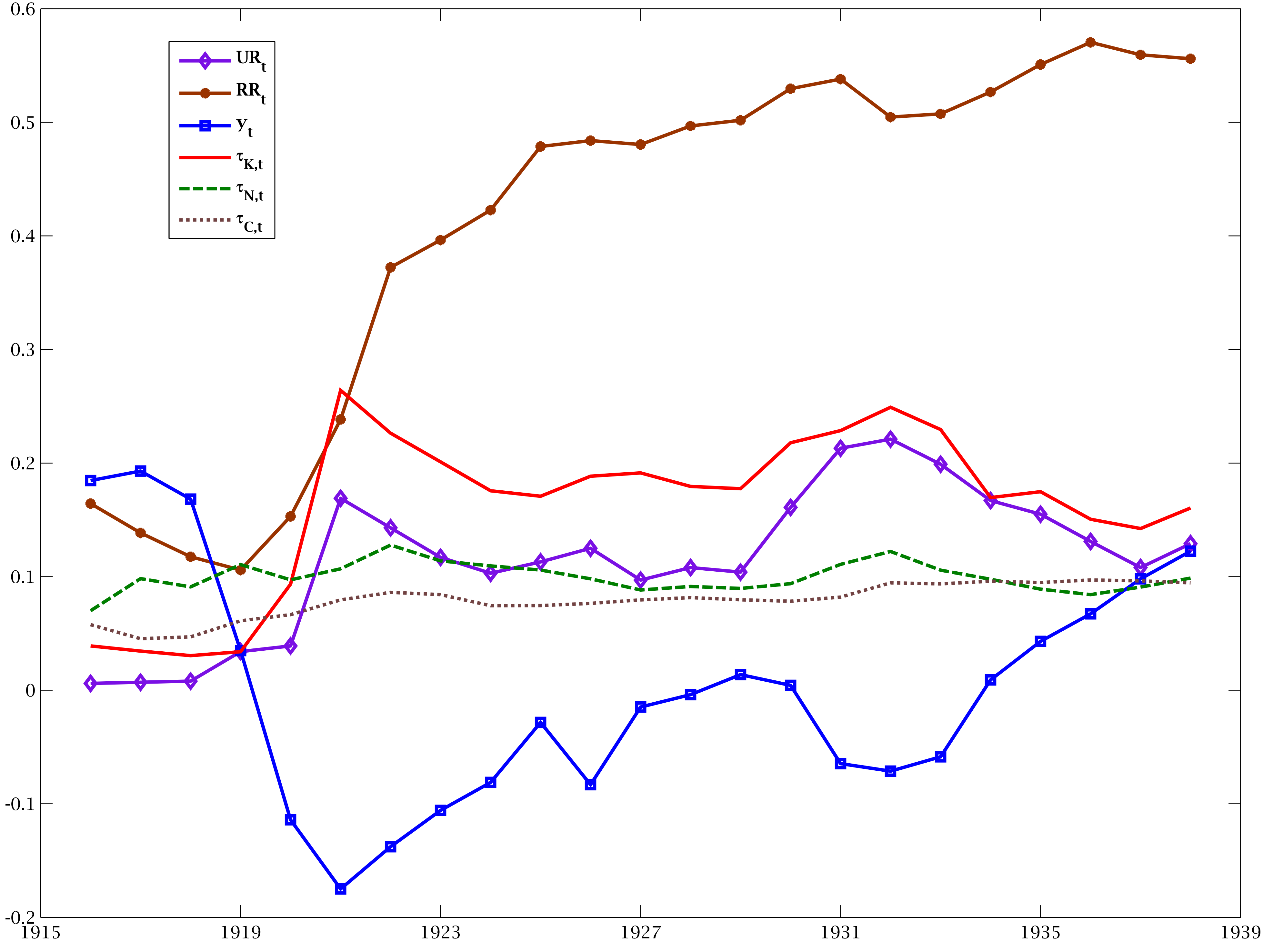


Fig. 4: Unemployment Rate, Replacement Ratio, Detrended Output, and Average Tax Rates, 1916-1938



Appendix

This appendix describes the sources and construction of the income growth accounting and Benjamin and Kochin (1979) regression time series. Tables A2, A3, and A4 and figure A1 are also found below.

A.1 UK Growth Accounting Data

Feinstein (1972) and Mitchell (1988) are the primary sources of our UK national income, tangible capital stock, per capita hours worked, and employment data. We obtain nominal national income from the "Compromise GDP" measure reported in Feinstein (1972, T12–T13). This nominal GDP series is in millions of current pounds at factor cost. The series is revised and extended by Mitchell (1988, p. 836). A real GDP index is reported by Feinstein (1972, T19) on a "compromise" basis with 1913 as the base year. Mitchell (1988, p. 836) revises and extends the nominal GDP and real GDP index. Our real output series is calculated by scaling the real GDP index with the 1913 nominal GDP observation. The real capital stock equals the net capital stock in millions of current pounds found in Mitchell (1988, pp. 865–866), scaled up by the inverse of one minus a fixed depreciation rate (equal to 0.109), and adjusted to the 1913 base year using the implied "compromise GDP" deflator. As discussed in section 2.2, per capita hours worked relies on the sum of civilian and armed services employment to measure total employment. The employment series are available in Feinstein (T126–7) measured in thousands of workers. These time series are presented in table A1.

A.2 Benjamin and Kochin (1979) Regression Data

This appendix describes the Benjamin and Kochin (1979) regression variables. Table A5 lists the data.

Benjamin and Kochin's unemployment rate series is found in Ormerod and Worswick (1982, table 1) from 1920 to 1938, which is taken from Feinstein (1972, T128). He provides unemployment rate data that are based on those workers covered by unemployment insurance. The 1919 observation is also given by Feinstein (1972, T126), whose data sources are trade union records. Mitchell (1988, p. 124) reports additional observations for the 1913–1918 period using similar sources and definitions. The 1913–1918, 1919, and 1920–1938 data are combined to obtain the unemployment rate, UR_t.

Ormerod and Worswick (1982) provide the replacement ratio series. Benjamin and Kochin calculate the series using average weekly wages of full-time employees from Chapman (1953) and benefit entitlements of an adult male with a spouse and two children from Burns (1941, table XI, p. 368). Benefits data prior to 1920 are also from Burns, but average weekly wages are from Feinstein (1972, T140) rather than Chapman. The pre-1920 data and Benjamin and Kochin's preferred series are spliced together to form the replacement ratio, RR_t, that this paper employs.

Benjamin and Kochin's output series is also found in Ormerod and Worswick (1982). They use real net national product in millions of 1938 pounds at factor cost that is available from Feinstein (1972, T15). This source also supplies observations from 1913 to 1919. Note that real net national product is not per capita. Subsequent to taking the log of real net national product from 1916 to 1938, it is regressed on an intercept and time trend. The regression residuals form y_t. The same procedure is used to create y_t on the 1920–1938 sample.

We use Benjamin and Kochin's preferred series in the regressions. This avoids issues of comparing our results to Benjamin and Kochin's and measurement problems discussed in the economic history literature. Nason and Vahey (2006) provide a summary and references of these problems. We experimented with alternative measures of UR_t, y_t, and RR_t that have been discussed in the literature. Our empirical results are robust across the alternative variable measures. Although there are a few differences in the levels across alternative variable measures, these variables exhibit qualitatively similar comovement with the UR_t in the 1920–1938 sample.

Table A1: Sample Statistics of UK Average Tax Rates and Per Capita Hours Worked, 1920–1938

	$\Delta\tau_K$	τ_N	$\Delta\tau_C$	$\Delta\ln h$	$\Delta\ln h_{Alt}$
$\overline{X}$	0.007	0.101	0.002	0.007	0.005
$\hat{\sigma}_X$	0.048	0.012	0.005	0.037	0.038
X_{Max}	0.171	0.128	0.013	0.031	0.055
X_{Min}	−0.060	0.084	−0.010	−0.136	−0.136
$\hat{\rho}_X(1)$	0.138	0.605	0.336	−0.035	0.007

The sample mean, standard deviation, maximum, minimum, and first-order autocorrelation coefficient are denoted by $\overline{X}$, $\hat{\sigma}_X$, X_{Max}, X_{Min}, and $\hat{\rho}_X(1)$, respectively.

Table A2: Sample Statistics of UK Average Tax Rates and Per Capita Hours Worked, 1925–1938

	$\Delta\tau_K$	τ_N	$\Delta\tau_C$	$\Delta\ln h$	$\Delta\ln h_{Alt}$
$\overline{X}$	−0.001	0.098	0.001	0.010	0.009
$\hat{\sigma}_X$	0.024	0.010	0.004	0.018	0.021
X_{Max}	0.040	0.122	0.012	0.031	0.055
X_{Min}	−0.060	0.084	−0.002	−0.026	−0.026
$\hat{\rho}_X(1)$	0.127	0.613	0.063	0.333	0.400

The sample mean, standard deviation, maximum, minimum, and first-order autocorrelation coefficient are denoted by $\overline{X}$, $\hat{\sigma}_X$, X_{Max}, X_{Min}, and $\hat{\rho}_X(1)$, respectively.

Table A3: UK World War I and Interwar Growth Accounting Summary Statistics, Based on $h_{Alt,t}$

Sample		Y	K	N	Z
1916–1938					
	$\overline{y}$	0.006	0.009	−0.006	0.010
	$\widehat{\sigma}_y$	0.046	0.047	0.076	0.067
	y_{Max}	0.074	0.141	0.080	0.188
	y_{Min}	−0.103	−0.115	−0.269	−0.195
	$\widehat{\rho}_y(1)$	0.220	−0.185	−0.008	−0.262
1920–1938					
	$\overline{y}$	0.010	0.011	0.000	0.010
	$\widehat{\sigma}_y$	0.044	0.046	0.073	0.073
	y_{Max}	0.074	0.141	0.080	0.188
	y_{Min}	−0.093	−0.115	−0.269	−0.195
	$\widehat{\rho}_y(1)$	0.300	−0.233	0.005	−0.262
1925–1938					
	$\overline{y}$	0.017	0.012	0.016	0.004
	$\widehat{\sigma}_y$	0.036	0.020	0.038	0.035
	y_{Max}	0.074	0.054	0.080	0.056
	y_{Min}	−0.057	−0.013	−0.055	−0.072
	$\widehat{\rho}_y(1)$	−0.038	0.184	0.370	−0.440

The sample mean, standard deviation, maximum, minimum, and first-order autocorrelation coefficient of the growth rates are denoted by $\overline{y}$, $\widehat{\sigma}_y$, y_{Max}, y_{Min}, and $\widehat{\rho}_y(1)$, respectively.

Table A4: UK GDP, Capital, Employment, and Population, 1913–1938

	Nominal GDP	Real GDP Index	Net Capital Stock	Civilian Employment	Military Employment	Population
1913	2244.0	100.0	4565.0	19910.0	400.0	45649.0
1914	2278.0	102.3	4642.0	19440.0	810.0	46049.0
1915	2746.0	108.8	5298.0	18400.0	2490.0	46340.0
1916	3218.0	110.9	6131.0	17700.0	3500.0	46514.0
1917	4082.0	111.7	7112.0	17100.0	4250.0	46614.0
1918	4920.0	114.1	8588.0	17060.0	4430.0	46575.0
1919	5202.0	102.8	10558.0	19030.0	2130.0	46534.0
1920	5439.0	91.3	13440.0	19537.0	760.0	43718.0
1921	4578.0	83.9	11060.0	17417.0	491.0	44072.0
1922	3995.0	88.2	9230.0	17483.0	392.0	44372.0
1923	3793.0	91.0	8510.0	17758.0	348.0	44596.0
1924	3877.0	94.8	8610.0	18032.0	346.0	44915.0
1925	4113.0	99.4	8700.0	18238.0	350.0	45059.0
1926	3870.0	95.7	8590.0	18244.0	349.0	45232.0
1927	4079.0	103.4	8560.0	18789.0	347.0	45389.0
1928	4103.0	104.7	8460.0	18868.0	336.0	45578.0
1929	4214.0	107.8	8660.0	19146.0	333.0	45672.0
1930	4185.0	107.0	8590.0	18788.0	327.0	45866.0
1931	3843.0	101.5	8410.0	18340.0	325.0	46074.0
1932	3746.0	102.3	8130.0	18430.0	323.0	46335.0
1933	3776.0	105.3	8080.0	18813.0	323.0	46520.0
1934	4016.0	112.2	8220.0	19360.0	325.0	46666.0
1935	4197.0	116.5	8560.0	19704.0	333.0	46868.0
1936	4389.0	121.8	9080.0	20321.0	349.0	47081.0
1937	4708.0	126.1	9860.0	20987.0	377.0	47289.0
1938	4959.0	127.6	10230.0	20986.0	432.0	47494.0

Nominal GDP is in millions of current year pounds, at factor prices. The net capital stock is also measured in millions of current year pounds. Civilian employment, military employment, and population are in thousands of workers, military personnel, and people. Appendix A.1 contains details about the GDP, capital, civilian and military employment, and population data.

Table A5: UK Unemployment Rate, Replacement Rate, and Real Net National Product, 1913–1938

	Unemployment Rate	Replacement Rate	Real Net National Product
1913	3.60	19.80	4085
1914	4.20	19.68	4118
1915	1.20	17.91	4469
1916	0.60	16.43	4515
1917	0.70	13.85	4579
1918	0.80	11.75	4492
1919	3.40	10.58	3954
1920	3.90	15.31	3426
1921	16.90	23.84	3242
1922	14.30	37.23	3384
1923	11.70	39.64	3514
1924	10.30	42.27	3622
1925	11.30	47.87	3840
1926	12.50	48.39	3656
1927	9.70	48.04	3937
1928	10.80	49.68	4003
1929	10.40	50.18	4097
1930	16.10	52.96	4082
1931	21.30	53.81	3832
1932	22.10	50.46	3828
1933	19.90	50.74	3899
1934	16.70	52.67	4196
1935	15.50	55.09	4365
1936	13.10	57.04	4498
1937	10.80	55.94	4665
1938	12.90	55.60	4807

The UK unemployment and replacement rates are in percentages. Real net national product is in millions of 1938 pounds at factor cost. Appendix A.2 discusses the sources of the unemployment rate (UR_t) and replacement rate (RR_t), along with estimating linear detrended output (y_t) as the residual of log real net national product on an intercept and time trend.

Fig. A1: U.K. WWI and Interwar Productivity Accounting, 1916-1938