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Interwar Inflation, Unexpected Inflation, and Output Growth

Bill Dorval
Queen's University

Gregor W. Smith
Queen's University

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

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Bill Dorval and Gregor W. Smith*

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Abstract

Interwar macroeconomic history is a natural place to look for evidence on the correlation between output growth and inflation or unexpected inflation. We apply time-series methods to measure unexpected inflation for more than twenty countries using both retail and wholesale prices. There is a significant, positive correlation between output growth and inflation for the entire period. There is little evidence that this correlation is caused by an underlying role for unexpected inflation. For wholesale price inflation in particular the output declines associated with deflations were larger than the output increases associated with inflations of the same scale.

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* Department of Economics, Queen's University, Kingston Ontario Canada K7L 3N6; dorvalb@econ.queensu.ca; smithgw@econ.queensu.ca. We thank the Social Sciences and Humanities Research Council of Canada and the Bank of Canada fellowship programme for support of this research. The views expressed herein are not necessarily those of the Bank of Canada and are the authors' alone. We thank conference participants at the Canadian Network for Economic History, Patrick Coe, Solomos Solomou, Kenneth West, and two referees of this journal for very constructive comments.

1. Introduction

The interwar period, with its volatility, multiple policy regimes, and international heterogeneity, is a natural place to look for lessons on business cycles and in particular for evidence on the relationship between monetary phenomena and the real economy. For example, numerous countries experienced deflations during the 1920s and 1930s, and so evidence from this period remains widely cited in more recent debates on the causes and implications of deflation. A variety of economic theories distinguish between the implications of the expected and unexpected components of inflation or deflation. Yet there is little research that tries to distinguish between these two components and study their correlations with output growth for multiple countries during the interwar period.

We use quarterly retail price indexes for 26 countries and wholesale price indexes for 24 countries in a time-series model, to try to distinguish between expected and unexpected inflation. We find considerable variation in inflation persistence across countries. Thus the extent to which the deflation of the early 1930s was expected to continue may well have differed significantly across countries too.

We then see whether there is a correlation between inflation and output growth, first in a cross-section of averages for 1930–1934 and second in the panel of countries year-by-year for 1922–1939 with retail price inflation and for 1921–1939 with wholesale price inflation. The cross-section provides little evidence of a significant correlation. But the panel data allow us to control for country-specific, average growth rates over the entire interwar period. In that statistical environment there is a clear, positive correlation between inflation and output growth. There is little evidence that this correlation reflects an underlying one between output growth and unexpected inflation. But there also is evidence that the growth-inflation relationship has a kink at zero, with deflations associated with larger output decreases than comparable inflations are with output increases.

2. Research Background

A key component in the research background is the study by Atkeson and Kehoe (2004). They found little historical evidence of a correlation between deflations and depressions. For the Great Depression, they measured average growth rates in real output over 1930–1934 for 16 countries, and regressed them on a constant and average inflation rates in this cross-section. They found a slope of 0.4 with a standard error of 0.28, thus providing some evidence of a link, albeit with low statistical significance. Notably, they found that the link was even weaker for other time periods. Thus they questioned the popular view that deflations are associated with depressions.

A second key component is the study by Benhabib and Spiegel (2009). They considered the possibility that the relationship might be nonlinear: positive at low or moderate inflation rates (or in deflations) but turning negative at high inflation rates, to form an inverted U-shape. They studied the same set of countries as Atkeson and Kehoe, again with averages within 5-year periods. By estimating in a panel, as opposed to a cross-section, they allowed for country-specific fixed effects in economic growth. Measuring the nonlinearity either with a term in squared inflation or using a threshold model, they found a nonlinear relationship that was positive below a threshold at a moderate level of inflation and negative or insignificant above it.

Our research also is related to studies for the US that try to measure the extent to which the ongoing deflation during the Great Depression was anticipated. Cecchetti (1992) argued that, once deflation began, it was largely anticipated at 3–6 month horizons. He found evidence for anticipated deflation in (a) the US history of deflations prior to 1929, (b) time-series models of the inflation rate, and (c) information in short-term nominal interest rates. His time-series modelling is particularly relevant to our approach below, since we do not have detailed information from fixed-income securities markets in the international panel. Cecchetti measured inflation quarterly, at annual rates, and for 1919–1940 found an AR(1) model had a coefficient of 0.52. Forecasts from this model suggested that up to three-quarters of ongoing deflation was anticipated, so that *ex ante* real interest rates were high, a likely cause of continued depression.

Nelson (1991) studied the contemporary business press and concluded that deflation was expected after the middle of 1930. In a similar vein, Romer and Romer (2013) tracked editorial opinion in *Business Week* and concluded that by the autumn of 1930 deflation was anticipated and, further, that this forecast was attributed to inaction by the Federal Reserve. They too concluded that the low nominal interest rates of the period were consistent with high, expected, real interest rates.

In contrast, Dominguez, Fair, and Shapiro (1988) summarized evidence both from vector autoregressions and from documentary sources and concluded that the US deflation was largely unanticipated. Hamilton (1992) observed that time-series models that have similar in-sample fit can generate forecasts that differ widely from one another. He thus supplemented these models with information from commodity futures markets, essentially using the historical link between commodity prices and the overall consumer price index as the observation equation in a Kalman filtering exercise. He concluded that expected deflations were only about half as severe as the actual deflations that occurred in the second and third years of the Great Depression. Evans and Wachtel (1993) described uncertainty about Federal Reserve policy as the Depression began, and modelled inflation expectations with a regime-switching model. They estimated investors' views of the probability of a return to stable prices by using information in monthly interest rates. Like Hamilton, they concluded the deflation was largely unanticipated. This finding implies that real interest rates were not so high once the Depression began, so that the propagation mechanism may have been through unexpected deflation causing bankruptcy instead. Overall then, this debate also reminds us that both anticipated and unanticipated deflation may have real effects.

Few studies examine the degree to which interwar deflations were expected for other countries. An exception is the study by Fregert and Jonung (2004), who looked at the reported beliefs of employers, workers, and policymakers in Sweden, and how they differed between the deflations of 1921–1923 and 1931–1933.

We too examine the links between inflation (or deflation) and output growth, particularly for the interwar period and for a large set of countries. We also see whether a readily-constructed measure of unanticipated inflation affects conclusions about the correlation between inflation and output growth. Our forecasting model uses the time-series properties of inflation (as in Cecchetti, 1992) largely because the additional information sources considered in the research on the US are not available for most other countries. We have not found existing studies that use a panel of countries to assess the correlation between unexpected deflation and the business cycle in the Great Depression or the interwar period more generally. This paper is an attempt to address this question.

3. The Information: Interwar Price and Output Data

We use both retail (or consumer) and wholesale price indexes from the League of Nations *Statistical Yearbook* for 32 countries. For the US retail price level we use the CPI from the Bureau of Labor Statistics (the original source of the League of Nations data) because it covers a longer time span. The starting dates vary from 1920 to 1928 while the available ending dates vary between 1938 and 1944. We end the sample at the second quarter of 1939 so as to focus only on the interwar period. Monthly data are available for some countries and time periods, but all results are reported for quarterly data for comparability. Table 1 contains the list of countries, the codes used to label them, and the country-specific time span of quarterly, retail price data. Wholesale price data are not described in table 1 but generally begin in 1920. They are unavailable for Greece, Ireland, and Romania but are available for an additional country: Spain.

Because the League of Nations price data begin in 1920 at the earliest, we do not capture all of the postwar deflations or inflations. For example the UK, US, Italy, and several other countries experienced inflation from 1919 to 1920. We also exclude episodes of hyperinflation in the early 1920s in Austria, Germany, Hungary, and Poland. However, there remains a great deal of heterogeneity in the inflation experiences in the panel. For example, the data include some of the deflations associated with the restoration of the gold standard in the early 1920s and those associated with the Great Depression, as well as episodes of inflation later in the 1930s. Price indexes of course exist for some countries earlier than 1920 but to our knowledge there is no international panel at high frequency before this period.

Real output is measured in millions of 1990 international Geary-Khamis dollars per capita. The source is Madison (2003), with significant updates by Bolt and van Zanden

(2013) to reflect recent research on historical national accounts. These series are at annual frequency. Asterisks in table 1 indicate countries for which real GDP data are available from the Maddison Project, overlapping with the League of Nations price data. This intersection includes 26 countries for retail prices and 24 countries for wholesale prices.

An alternative to this combination of the League of Nations and Maddison data is to use measures of real output and output deflators from Mitchell's (2003) *International Historical Statistics*. These data have three drawbacks relevant to use in our study, however. First, they are at annual frequency. That means there are not enough time-series observations for them to be used to estimate a 4-quarter inflation forecast and measure expected inflation. In contrast, the League of Nations data allow quarterly observations on forecasts at this horizon. Second, the measures apply to GDP, GNP, NNP, or even switch between these depending on the country. Third, the number of countries is 20, as opposed to 24 or 26 with our sources, so that the Mitchell panel is smaller.

Let p_{it} denote the price index in country i and quarter t. The inflation rate is measured as the 4-quarter growth rate of the price index:

$$\pi_{it} = 100 \cdot \left[\left(\frac{p_{it}}{p_{it-4}} \right) - 1 \right]. \tag{1}$$

This inflation rate (as opposed to the annualized, quarter-to-quarter rate) seems appropriate because we later look at its correlation with the growth rate of real GDP, which is measured at annual frequency.

For retail price inflation, table 2 contains the means, standard deviations, and standard deviations relative to the United States, for the panel of inflation rates. Average inflation rates varied widely across countries, with Belgium, France, Greece, Luxembourg, and Romania all having average inflation over 4% at annual rates, while 18 of the 32 countries—including the US and UK—on average experienced deflation. US inflation volatility (as measured by the standard deviation) also was relatively low. Again there was considerable variation across countries in this statistical moment.

4. Forecasting Model

Several sources of information available to the modern forecaster of inflation are not present for the interwar period. National income accounts are available only at annual frequency. We do not have access to surveys of professional forecasts (with one or two infrequent exceptions), to inflation-indexed bond prices or, indeed, to natural covariates such as unemployment rates or output gaps at high frequency. There is ongoing research on the role of these covariates in forecasting inflation in contemporary data, as discussed by Stock and Watson (2007) and Faust and Wright (2012), but we cannot check on that role for most countries in the interwar period.

Thus we focus on univariate, time-series methods for forecasting. We estimate:

$$\pi_{it} = \mu_i + \rho_i \pi_{it-4} + \omega_i p_{it-4} + \epsilon_{it}, \tag{2}$$

where t counts quarters and ϵ_{it} is an error term assumed to have mean zero and be uncorrelated with the regressors. This forecasting model has the appealing features that it involves only three parameters per country and it tends to remove any seasonality in inflation. Most importantly, its forecasts can be averaged over quarters to produce realistic, annual forecasts, given the 4-quarter lag, yet it still uses the high frequency of the price data to add precision as opposed to simply estimating a time-series model in annual averages.

The parameter ρ_i—varying across countries—captures the persistence in actual inflation and hence potentially estimates a property of expectations. The parameter ω_i allows for mean reversion (stationarity) in the price level or, equivalently, an error-correction setup in which the inflation rate also responds to the difference between the price level (lagged 4 quarters) and a constant. When ω_i is negative a low (high) price level tends to be followed by relatively high (low) inflation over the subsequent year. Including this parameter thus allows for the possibility that an episode of deflation leads to expectations of reflation. We tested the null hypothesis that there is a unit root in the price level at the annual frequency using the test of Hylleberg, Engle, Granger, and Yoo (1990) country-by-country and rejected it for all countries at conventional significance levels. Thus, the quarterly data suggest that there was indeed mean reversion in interwar prices.

Forecasting 4 quarters ahead is challenging, and may differ from forecasting 1 quarter ahead. But we adopt this 4-quarter horizon in the forecasting equation (2) and the definition of inflation as the 4-quarter change (1) so that we can also measure the inflation surprise at the annual horizon. The goal is then to align this with the output growth rates, which are available only annually. It also would be interesting to study the 1-quarter-ahead predictability of quarter-to-quarter inflation for this panel, but we do not study that issue in this paper. Future work also might consider adding to the forecasting information set, with indicators including the inflation rates of neighboring countries, the exchange-rate change, or gold-standard status.

We represent the inflation forecasts in two ways, First we forecast inflation using parameter estimates $\{\hat{\mu}_i, \hat{\rho}_i, \hat{\omega}_i\}$ from the full interwar sample, so that forecasted inflation is:

$$E_{t-4}\pi_{it} = \hat{\mu}_i + \hat{\rho}_i\pi_{it-4} + \hat{\omega}_i p_{it-4}. \quad (3)$$

This approach has the advantage of yielding forecasts for the entire period.

Table 3 gives parameter estimates from full-sample estimation, for quarterly inflation rates measured with both retail and wholesale price indexes, for the countries for which Maddison (2003) and Bolt and van Zanden (2013) provided output data. Standard errors are robust to residual autocorrelation. Notice that each value of $\hat{\omega}_i$ is negative and a number of these values are statistically significant. For a number of countries a high price level a year ago thus is associated with lower subsequent inflation, and vice versa. We also estimated a version of the forecasting model in which the inflation rate responds to the lagged logarithm of the price level, rather than the price level itself. The goodness-of-fit was very similar and so the results are not shown.

Figure 1 graphs retail price inflation (the solid, black line) and expected inflation (the dashed, gray line) for the US, using the full-sample parameter estimates from table 3 to construct 4-quarter-ahead forecasts. For the US the estimated value of the persistence parameter, $\hat{\rho}_i$, is 0.41, so that forecasts adjust to recent inflation experience with this weight. (They also adjust to the past price level with coefficient $\hat{\omega}_i$, but that value is very small for the US.) Figure 1 suggests that the deflation of the early 1930s was largely unexpected, but that the scale of the shock declined over time (or some deflation became expected), as expectations caught up with actual inflation to some extent. Table 3 shows that the value of $\hat{\rho}_i$ is higher for several other countries, including Germany and Japan. For those countries the fit of the forecasting model also is better and so unexpected inflation or deflation is less variable than estimated for the US. We later test whether larger inflation surprises are associated with larger movements in real output.

Second, we also construct recursive estimates that use only data prior to the date of the forecast, so that forecasted inflation is:

$$E_{t-4}\pi_{it} = \hat{\mu}_{it-4} + \hat{\rho}_{it-4}\pi_{it-4} + \hat{\omega}_{it-4}p_{it-4}, \tag{4}$$

where the time subscript on the parameters denotes the last observation used in estimation. We construct the first forecast when there are 8 quarterly observations in the estimation. But if that first forecast is not the first quarter of a calendar year, we continue to add observations and defer forecasts until that condition is satisfied. That way, the annual averaging always involves the same number of actual inflation rates and forecasted ones, and the annual averages of expected and unexpected inflation always add up to actual inflation for each year.

A benefit of adopting the recursive approach is that it uses no information from the properties of inflation in the 1930s to estimate the parameters for constructing expected inflation during the 1920s. But the recursive estimates of expected inflation do require a starting date later than the first available data point, and even then the recursive estimates early in the sample are based on relatively few observations. The delayed starting date means that we do not measure unexpected deflations in 1921 or 1922 using these specific measures. In any case, it might be difficult to argue they could be predicted from previous history even were price indexes available for the prior decade and the 1914–1918 War. But we do use the properties of such deflations to parametrize the forecasting models and hence measure inflation expectations in the deflations of the 1930s, which are a key feature of this historical period.

5. Inflation and Output Growth on Average, 1930–1934

In their study of deflations, Atkeson and Kehoe (2004) pointed out that there generally is little evidence of a correlation between deflation and low growth in historical data. But the one episode for which they *did* find a correlation was the Great Depression, and specifically the period from 1930 to 1934 (which thus involves the levels of output and prices from 1929 to 1934). They studied a group of 16 countries, and illustrated their findings with a scatter plot of real output growth against inflation, with averages for each country over those 5 years.

In this section we first duplicate their method for a larger set of 26 countries. Second, as they noted (p 99) "we have made no attempt to distinguish anticipated from unanticipated deflations, while theory, of course, makes a sharp distinction." We use the recursive and full-sample forecasting models from section 4 to make this distinction and repeat the scatter plot using the resulting measures of unexpected inflation or deflation. Third, we apply the method using wholesale as well as retail prices.

To construct annual measures of inflation and unexpected inflation corresponding to annual growth rates in real output, we average the corresponding quarterly measures within calendar years. We then average a second time, over the years 1930–1934, just as Atkeson and Kehoe did. Our measures of unexpected inflation rely on quarterly price indexes. We have such measures for 12 of the 16 countries studied by Atkeson and Kehoe: Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Sweden, the UK, and the US. As for the remaining 4 countries in the Atkeson-Kehoe study, we do not have data for Argentina, Brazil, or Portugal and for Spain our only data are for wholesale prices. But we do have data for 14 additional countries, labelled with asterisks in table 1.

Figure 2 shows the scatter plot of average output growth during 1930–1934, on the vertical axis, against average retail price inflation, on the horizontal axis, for all 26 countries. The dark circles represent actual inflation rates, while the light circles represent unexpected inflation rates, estimated using the full sample as in equation (3). Thus the horizontal distance between the two, for a given country, is the expected inflation rate.

Notice that 25 of the 26 countries experienced deflation, on average, during this 5-year period. Greece is the one exception. But their average, annual output growth rates varied between -5.8% for Canada and 2.0% for Finland. Overall, figure 2 provides little evidence of a correlation between inflation and output growth or, in this case, deflation and depression. This negative finding is influenced by countries such as Austria, which experienced a prolonged recession with relatively modest deflation, and Japan, the UK, and Sweden, which experienced modest growth on average with significant deflation.

We also used a regression to test for a a linear relationship between average output growth and either inflation or unexpected inflation. Unexpected inflation was estimated two ways, first using the full sample and then recursively. And inflation was measured with either retail or wholesale prices. The sign of the coefficient linking the variables was sometimes positive, but its p-value was relatively small (0.08) only in the case of the regression for actual, wholesale inflation, in which the R^2 statistic was 0.13. These findings thus confirm the impression from figure 2.

We have added additional countries, wholesale prices, and time-series-based measures of unexpected inflation or deflation to Atkeson and Kehoe's study. But, if anything, these steps weaken the evidence for a positive correlation between inflation and growth from 1930 to 1934. Studying the correlation in a cross-section of averages raises two statistical issues, however. First, there may be information in the year-by-year observations for each country that is obscured by the 1930–1934 averages. Second, there may be a difference in average output growth rates across countries, unrelated to rates of inflation or deflation, that one needs to control for in measuring the impact of inflation surprises. Atkeson and Kehoe (2004, p 102) argued that "standard theories, either neoclassical or new Keynesian, would have a hard time blaming Japan's secular growth slowdown [from the 1960s to the 1990s] on its secular decline in inflation." We concur and similarly would like to allow for differences in average growth rates over the entire interwar period that may be due to growth convergence or other features unrelated to inflation or deflation. The next section studies these issues.

6. Inflation and Output Growth Year-by-Year, 1921/1922–1939

To further study the correlation between inflation and output growth we next examine the interwar history year-by-year, with years indexed by the subscript τ. Data begin in 1922 for retail price inflation and in 1921 for wholesale price inflation, ending in 1939 in each case. We relate output growth in country i and year τ, $\dot{y}_{i\tau}$, to realized inflation and unexpected inflation, both together and individually. To illustrate the notation, the estimating equations thus are:

$$\dot{y}_{i\tau} = \alpha_i + \beta_\pi \pi_{i\tau} + \beta_u(\pi_{i\tau} - E_{\tau-1}\pi_{i\tau}) + \epsilon_{i\tau}. \quad (5)$$

Inflation and unexpected inflation are averaged over the quarters within each calendar year whenever at least two quarters of data are present. For 1939 we average inflation over only the first two quarters, so as to exclude wartime data.

With a relatively short panel, working with growth rates and country-specific intercepts (fixed effects) seems a reasonable specification. With the added time-series dimension, we now can identify a value α_i specific to each country. The underlying economic assumption is that a component of the long-term, average growth rate over this period was not related to the inflation rate. Benhabib and Spiegel (2009) also controlled for country fixed effects, in averages over successive 5-year periods.

Table 4 presents results from several special cases of equation (5) for retail price inflation (in the upper panel) and wholesale price inflation (in the lower panel). The number of observations reflects the fact that the starting date for the data varies by country as shown in table 1. Estimating using forecasts with the full-sample estimates involves the loss of one year's data for each country, because of the lagged, dependent variable in the forecasting model (2). Forecasting recursively involves a 2-year start-up period that further reduces the number of observations.

For retail price inflation, the first row of table 4 contains the actual inflation rate as the only regressor and finds it to have a coefficient of 0.29 with t-statistic of 4.8. An inflation rate of 1% per year thus is associated with output growth of 0.29% per year. The contrast with the lack of correlation in section 5 (figure 2) may be due to the longer time span, the lack of time-averaging, or the inclusion of the country-specific fixed effects which were not controlled for there.

The second row summarizes the regression with only unexpected inflation—measured with full-sample forecasts—and finds that it too is significant at conventional levels of significance. However, the third row contains results with both regressors, showing that the coefficient on unexpected inflation is statistically insignificant when actual inflation is included. The fourth and fifth rows then repeat this exploration but with unexpected inflation measured with recursive forecasts. The result is the same. There is a clear correlation between actual inflation in retail prices and growth in real output once we control for country-specific trends.

Table 4 does not show estimates from any regressions that include expected inflation, because the results are known automatically. Notice that equation (5) can be rearranged as:

$$\dot{y}_{i\tau} = \alpha_i + (\beta_u + \beta_\pi)\pi_{i\tau} - \beta_u E_{\tau-1}\pi_{i\tau} + \epsilon_{i\tau}. \tag{6}$$

Finding that $\hat{\beta}_u$ is insignificantly different from zero thus tells us that expected inflation will not play a significant role when actual inflation is included in the regression. Equation (5) also can be rearranged as:

$$\dot{y}_{i\tau} = \alpha_i + \beta_\pi E_{\tau-1}\pi_{i\tau} + (\beta_u + \beta_\pi)(\pi_{i\tau} - E_{\tau-1}\pi_{i\tau}) + \epsilon_{i\tau}. \tag{7}$$

Finding that $\hat{\beta}_u$ is insignificantly different from zero thus also tells us that the regression on unexpected inflation and expected inflation yields indistinguishable coefficients, so that the combination of variables in equation (7) reproduces actual inflation. Actual inflation thus is the clear winner in this contest to statistically explain the time-series variation in output growth rates.

For wholesale price inflation the results (in the lower panel of table 4) are more nuanced. Again actual inflation clearly is correlated with output growth. But now there is an additional, partial correlation between output growth and unexpected inflation (at the 10% level of significance) when we forecast inflation with the full-sample parameter estimates. Equivalently, given equation (6), expected inflation is significant at the 10%

level when combined with actual inflation. But with the recursive estimates there is again no statistical role for unexpected inflation once actual inflation is included.

Notice that the expected and unexpected inflation rates are generated regressors in that constructing them involves sampling variability in the forecasting coefficients, $\{\hat{\mu}_i, \hat{\rho}_i, \hat{\omega}_i\}$. Pagan (1984) showed that the OLS standard error for *unexpected* inflation is valid, when it is the only regressor, as in the second row of each panel in table 4, or when combined with expected inflation as in equation (7). But when we use actual inflation and unexpected inflation as regressors, the usual standard errors will be under-stated in general. We therefore also constructed standard errors that correctly reflect the uncertainty about the parameters of the forecasting model, using the method of Murphy and Topel (1985). However, these were very similar to the unadjusted ones, and these calculations change nothing reported in table 4. The logic is that $\hat{\beta}_u$ is quite small. That value scales the impact of the correction (from Murphy and Topel's theorem 1, where the corresponding coefficient is labelled $\hat{\gamma}$) so the overall correction is small also.

Several statistical extensions to these regressions come to mind, but are not practical for the interwar period. Either adding further dynamics or studying country-specific correlations is challenging because of the annual frequency and thus the limited number of observations of the interwar output data. For a small number of countries with high-frequency data one could estimate a vector autoregression and use it to measure surprises in inflation or deflation and their impacts. Smith (2006) summarizes some existing work in this vein for the interwar period.

7. Kinks and Curves

Table 4 shows that one can find a linear, statistical relationship between inflation and output growth in the interwar panel, whether with retail or wholesale prices. We next check for evidence of nonlinearities by seeing how robust the findings are to changes in the functional form. The results are collected in table 5.

First, it is possible that the correlation between inflation and growth differed depending on whether the inflation rate was positive or negative. We use a dummy variable $d_{i\tau}$

to denote observations with deflation, and by interacting this with actual inflation allow for the correlation between inflation and output growth to differ between inflations and deflations. The regression model then becomes:

$$\dot{y}_{i\tau} = \alpha_i + (\beta_\pi + \delta d_{i\tau})\pi_{i\tau} + \epsilon_{i\tau}. \tag{8}$$

Thus the estimated slope is $\hat{\beta}_\pi$ for inflations and $\hat{\beta}_\pi + \hat{\delta}$ for deflations.

The top panel (a) of table 5 shows the results. The estimates $\hat{\delta}$ (with standard errors in brackets) are 0.14 (0.19) for retail price inflation and 0.18 (0.07) for wholesale price inflation. In both cases, then, the coefficient linking deflation and output growth is greater than the one linking inflation and output growth. And for wholesale price inflation this kink at an inflation rate of zero is statistically significant at the 5% level. The output declines associated with deflations are larger than the output increases associated with inflations of the same scale.

Second, it also is possible that the relationship is monotonic but involves other kinks or curves. In that case, a linear regression would be misspecified. But a simple nonparametric method is available to check on that possibility. We rank each observation on inflation and on output growth, then run the linear regression with the ranks instead of the original observations. The linear functional form will be valid in ranks, even if the underlying relationship between inflation and output growth is nonlinear, as long as that relationship is monotone. Rank regression also may avoid some measurement errors if they are small enough not to affect ranks. Conover (1999, section 5.6) provides an introduction and examples of this method.

Define $R[x]$ as the rank statistic for a variable x. Then the regression is:

$$R[\dot{y}_{i\tau}] = \alpha_i + \lambda_\pi R[\pi_{i\tau}] + \epsilon_{i\tau}. \tag{9}$$

The fixed effects, α_i, control for country-specific average ranks of output growth rates over the interwar period.

The middle panel (b) of table 5 contains the results. The coefficients $\hat{\lambda}_\pi$, with standard errors in brackets, are 0.34 (0.05) for retail price inflation and 0.37 (0.05) for wholesale price inflation. With just a constant term α included the coefficients become Spearman's rank correlation coefficients. These are 0.30 (0.05) for retail prices and 0.35 (0.05) for wholesale prices. These positive, rank correlations are not large but they are statistically significant at the 1% level of significance. Overall, then, there is evidence of a positive relationship between inflation and output growth.

Third, Benhabib and Spiegel found that the correlation becomes negative at high inflation rates, so the relationship is not monotone, using 5-year averages for 17 countries from 1859–2009. We follow one of their methods by including a term in squared inflation, specifically to see if its coefficient is negative, capturing an inverted U-shape. The regression is:

$$\dot{y}_{i\tau} = \alpha_i + \beta_\pi \pi_{i\tau} + \gamma_\pi \pi_{i\tau}^2 + \epsilon_{i\tau}. \tag{10}$$

The results are in the lower panel (c) of table 5. Squared inflation enters with a negative coefficient—suggesting a non-monotone curve—but with a p-value of 0.92 for retail price inflation and one of 0.13 for wholesale price inflation. Thus there is no negative association between high inflation and growth in this panel, at conventional levels of statistical significance.

By comparison with Benhabib and Spiegel, we study more countries but over a shorter time span for the interwar period only, and with year-by-year data rather than 5-year averages. One might suspect the annual data are simply noisier, but the goodness of fit in our panel estimation is similar to theirs. Like these authors, we are studying correlations rather than a causal model of output growth or inflation. But possibly even high inflation rates (other than the central European hyperinflations of the early 1920s) were associated with growth during the interwar period because they followed after deflations and so represented returns to more normal price levels. Figure 1 shows this pattern for inflation in the US during 1934 when inflation was temporary, rather than heralding a shift to a permanently high rate of inflation, and offset previous deflation. Our forecasting model (2) also yielded some evidence of this mean-reverting pattern, in the form of negative coefficients $\hat{\omega}_i$.

8. Conclusion

This study has re-examined the relationship between inflation and growth for more than twenty countries during the interwar period, a time of volatility in both real and nominal macroeconomic variables. It also examined the further issue of whether the statistical relationship was due to an underlying correlation with unanticipated inflation.

To model expectations we take advantage of quarterly price data to study a forecasting model with a one-year horizon. We find considerable variation across countries in the persistence of inflation and so possible variation across countries in inflation expectations at the onset of the Great Depression.

We then complement the studies of Atkeson and Kehoe (2004) and Benhabib and Spiegel (2009) by examining data from a larger set of countries and including these measurements of unexpected deflation. From the cross-section of countries during 1930–1934 there is little evidence of a correlation between output growth and either inflation or unexpected inflation. But when we use time-series variation to identify the effect (and allow for country-specific, average, output growth rates over the entire interwar period) there is a clear correlation between output growth and actual inflation. For the full interwar period a 1% retail inflation rate is associated with a real growth rate of 0.18–0.39% with 95% confidence.

There are three other noteworthy findings. First, unexpected retail inflation has no statistically significant correlation with output growth once we control for actual inflation. There is some evidence of an additional, partial correlation between output growth and unexpected wholesale inflation, but only for forecasts based on full-sample estimates and at the 10% level of significance. Second, there is some evidence (again especially for wholesale price inflation) that the relationship between output growth and inflation is nonlinear, with a kink at zero and a steeper slope for deflations than inflations. Third, there is no significant evidence of the slope becoming negative at high inflation rates. Bursts of inflation in the interwar period (with the notable exception of the hyperinflations of the 1920s) often were reflations, temporary sequels to deflations, a feature which may explain this finding.

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Table 1: Countries and Time Spans for Retail Price Data

Country	Code	Time Span	Country	Code	Time Span
Australia*	aus	1921q1–1939q2	Italy*	ita	1921q1–1939q2
Austria*	aut	1923q1–1938q1	Japan*	jpn	1928q1–1939q2
Belgium*	bel	1922q1–1939q2	Latvia	lva	1921q1–1939q2
Bulgaria*	bgr	1922q1–1939q2	Lithuania	ltu	1924q1–1939q2
Canada*	can	1921q1–1939q2	Luxembourg	lux	1921q2–1939q2
Czechoslovakia*	cze	1923q3–1939q2	Netherlands*	nld	1921q1–1939q2
Denmark*	dnk	1926q3–1939q2	New Zealand*	nzl	1925q3–1939q2
Egypt	egy	1921q1–1939q2	Norway*	nor	1921q1–1939q2
Estonia	est	1924q3–1939q2	Peru*	per	1924q1–1939q2
Finland*	fin	1921q1–1939q2	Poland*	pol	1924q1–1939q2
France*	fra	1921q1–1938q4	Romania*	rom	1922q1–1939q2
Germany*	deu	1924q1–1939q2	South Africa	zaf	1922q1–1939q2
Greece*	grc	1923q2–1939q2	Sweden*	swe	1921q1–1939q2
Hungary*	hun	1925q1–1939q2	Switzerland*	che	1921q1–1939q2
India*	ind	1921q1–1939q2	United Kingdom*	gbr	1921q1–1939q2
Ireland*	irl	1922q2–1939q2	United States*	usa	1921q1–1939q2

Source: League of Nations *Statistical Yearbook* and Bureau of Labor Statistics. Asterisks denote countries with annual real GDP data from Maddison (2003) and Bolt and van Zanden (2013).

Table 2: Summary Statistics for Retail Price Inflation

Country	Mean	SD	Relative SD	Country	Mean	SD	Relative SD
aus	-0.6	4.9	1.1	ita	0.6	8.3	1.9
aut	1.9	5.8	1.3	jpn	1.7	9.0	2.1
bel	5.5	11.7	2.7	lva	2.1	11.7	2.7
bgr	-1.2	9.4	2.2	ltu	-4.0	9.7	2.3
can	-1.0	4.0	0.9	lux	4.1	11.7	2.7
cze	1.0	3.4	0.8	nld	-1.8	3.8	0.9
dnk	0.2	3.3	0.8	nzl	-0.2	4.4	1.0
egy	-2.1	3.9	0.9	nor	-2.7	6.9	1.6
est	0.6	6.7	1.6	per	-0.3	4.8	1.1
fin	-0.4	3.9	0.9	pol	0.7	9.9	2.3
fra	5.4	10.2	2.4	rom	6.0	13.2	3.1
deu	0.1	5.0	1.2	zaf	-0.5	2.4	0.6
grc	4.1	8.0	1.9	swe	-1.7	5.0	1.2
hun	-0.3	6.2	1.4	che	-2.1	6.0	1.4
ind	-2.6	6.0	1.4	gbr	-1.7	4.7	1.1
irl	-0.4	3.8	0.9	usa	-1.3	4.3	1.0

Sources: League of Nations *Statistical Yearbook* and Bureau of Labor Statistics. Entries are means and standard deviations of 4-quarter inflation rates. The relative SD is the ratio of the standard deviation to that in the US. Country codes are given in table 1.

Table 3: Full-Sample Inflation Forecast Regressions

$$\pi_{it} = \mu_i + \rho_i \pi_{it-4} + \omega_i p_{it-4} + \epsilon_{it}$$

	Retail Prices				Wholesale Prices			
Country	$\hat{\rho}_i$ (se)	$\hat{\omega}_i$ (se)	Obs	R_i^2	$\hat{\rho}_i$ (se)	$\hat{\omega}_i$ (se)	Obs.	R_i^2
aus	0.33	-0.13*	66	0.16	-0.01	-0.27***	70	0.16
	(0.22)	(0.07)			(0.10)	(0.10)		
aut	0.03	-0.78***	53	0.62	0.05	-0.31**	57	0.14
	(0.10)	(0.20)			(0.10)	(0.14)		
bel	0.14	-0.42**	62	0.39	0.27**	-0.53***	64	0.29
	(0.10)	(0.15)			(0.12)	(0.15)		
bgr	0.21	-0.10	62	0.05	0.30**	-0.31**	54	0.24
	(0.15)	(0.08)			(0.12)	(0.15)		
can	0.40*	-0.13	66	0.22	0.18	-0.15*	70	0.15
	(0.20)	(0.08)			(0.13)	(0.08)		
cze	0.08	-0.31	56	0.04	-0.06	-0.13**	66	0.20
	(0.32)	(0.48)			(0.09)	(0.06)		
dnk	0.70***	-0.31***	44	0.49	0.13	-0.16	68	0.15
	(0.15)	(0.08)			(0.14)	(0.12)		
fin	0.43***	-0.17*	66	0.25	0.09	-0.47***	65	0.27
	(0.15)	(0.10)			(0.15)	(0.14)		
fra	0.23	-0.29***	64	0.26	0.50***	-0.55***	70	0.39
	(0.19)	(0.10)			(0.12)	(0.17)		
deu	0.56***	-0.24**	54	0.48	0.56***	-0.19**	54	0.45
	(0.18)	(0.09)			(0.19)	(0.08)		
grc	0.28**	-0.41***	57	0.45	—	—	—	—
	(0.11)	(0.10)						
hun	0.39**	-0.35**	50	0.26	0.06	-0.31**	54	0.21
	(0.18)	(0.14)			(0.12)	(0.14)		
ind	0.03	-0.09	66	0.06	0.16	-0.07	70	0.08
	(0.09)	(0.06)			(0.18)	(0.04)		
irl	0.22*	-0.19**	61	0.16	—	—	—	—
	(0.12)	(0.09)						

[continued on the next page]

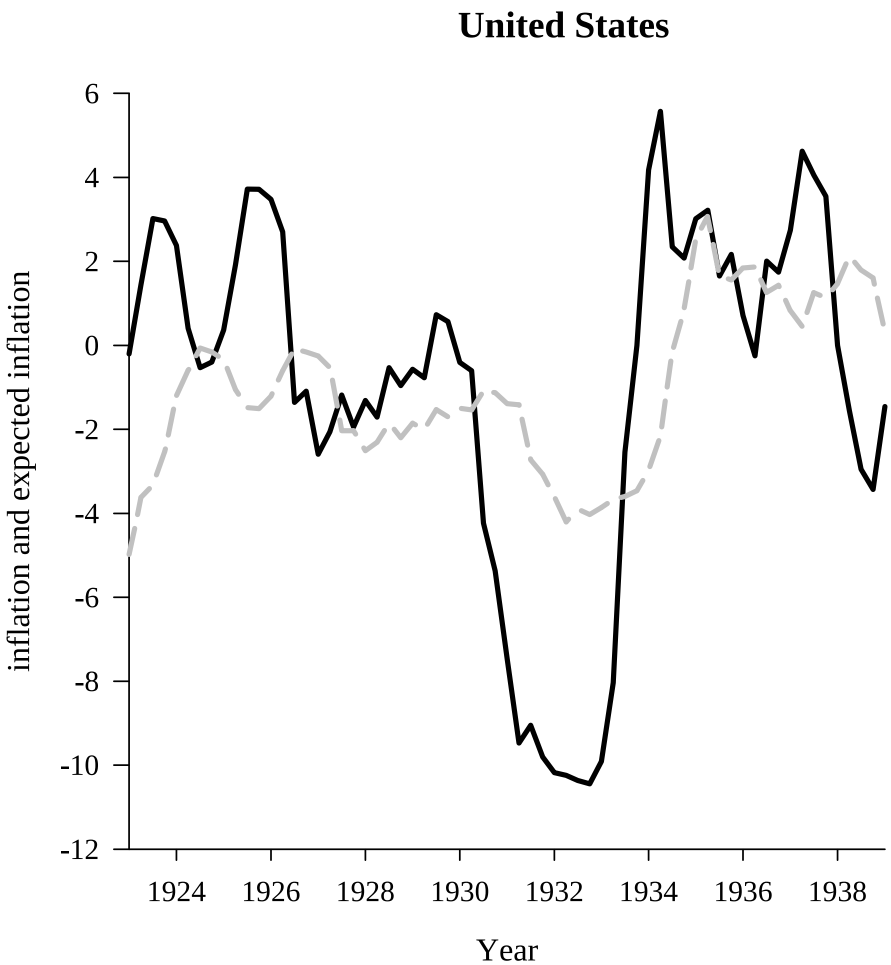
Table 3: Full-Sample Inflation Forecast Regressions [continued]

$$\pi_{it} = \mu_i + \rho_i \pi_{it-4} + \omega_i p_{it-4} + \epsilon_{it}$$

	Retail Prices				Wholesale Prices			
Country	$\hat{\rho}_i$ (se)	$\hat{\omega}_i$ (se)	Obs	R_i^2	$\hat{\rho}_i$ (se)	$\hat{\omega}_i$ (se)	Obs.	R_i^2
ita	0.53**	-0.37***	66	0.35	0.45***	-0.14*	70	0.27
	(0.21)	(0.13)			(0.14)	(0.07)		
jpn	0.92***	-0.38	38	0.58	0.23	-0.18**	70	0.16
	(0.24)	(0.25)			(0.17)	(0.08)		
nld	0.21	-0.08	66	0.11	0.24*	-0.06	70	0.15
	(0.14)	(0.07)			(0.14)	(0.06)		
nzl	0.72***	-0.27***	48	0.61	0.44***	-0.29***	50	0.33
	(0.14)	(0.08)			(0.14)	(0.08)		
nor	0.24	-0.08	66	0.19	0.24*	-0.12*	70	0.28
	(0.17)	(0.07)			(0.14)	(0.06)		
per	0.41**	-0.29***	54	0.39	0.28***	-0.35**	67	0.22
	(0.19)	(0.06)			(0.10)	(0.14)		
pol	0.72***	-0.20***	54	0.68	0.70***	-0.23***	54	0.50
	(0.13)	(0.07)			(0.18)	(0.08)		
rom	0.37***	-0.37***	62	0.48	—	—	—	—
	(0.13)	(0.12)						
esp	—	—	—	—	0.47***	-0.17	70	0.26
					(0.13)	(0.15)		
swe	0.27***	-0.14*	66	0.53	0.17	-0.19***	70	0.46
	(0.06)	(0.07)			(0.11)	(0.06)		
che	0.08	-0.06	66	0.05	0.23	-0.10	65	0.13
	(0.14)	(0.07)			(0.20)	(0.08)		
gbr	0.23**	-0.10*	66	0.26	0.06	-0.18***	70	0.19
	(0.09)	(0.06)			(0.10)	(0.07)		
usa	0.41*	-0.09	66	0.21	0.05	-0.15	70	0.08
	(0.23)	(0.07)			(0.15)	(0.12)		

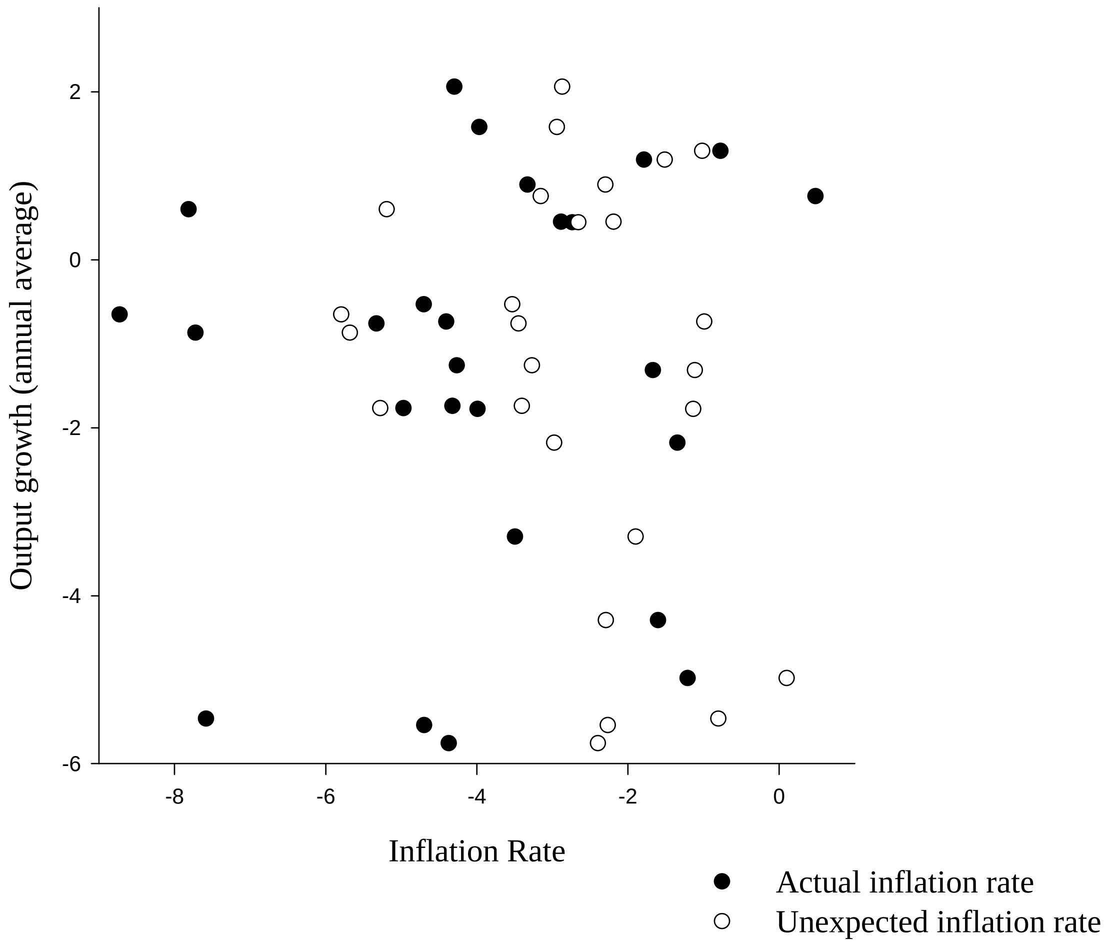
Notes: π_{it} is the quarterly observation on the 4-quarter inflation rate. Country codes and quarterly time spans are given in table 1. Obs is the number of quarterly observations. Newey-West (with 4 lags) standard errors are in parentheses. p-values less than 0.01 are denoted ***, less than 0.05 are denoted **, and less than 0.10 are denoted *.

Figure 1: Quarterly Inflation and Expected Inflation



Note: The solid line shows quarterly observations on 4-quarter inflation rates in the consumer (retail) price index from the Bureau of Labor Statistics. The dashed line shows the 4-quarter-ahead expected component: fitted values from the full-sample forecasting model (3) in section 4.

Figure 2: Average Annual Inflation and Real Output Growth 1930-1934
26 Countries



Note: Output growth is the annual average for each of 26 countries during 1930-1934, from Maddison (2003) and Bolt and van Zanden (2013). Dark circles represent actual retail price inflation rates, averaged from four-quarter rates. Light circles represent unexpected inflation rates, estimated from the full sample using the forecasting equation (3).

Table 4: Output Growth and Inflation Regressions

$$\dot{y}_{i\tau} = \alpha_i + \beta_\pi \pi_{i\tau} + \beta_u(\pi_{i\tau} - E_{\tau-1}\pi_{i\tau}) + \epsilon_{i\tau}$$

Price Measure Time Span	Observations Forecast Type	$\hat{\beta}_\pi$ (se)	$\hat{\beta}_u$ (se)	R^2
Retail 1922–1939	411	0.29*** (0.06)		0.14
	388 Full-Sample		0.37*** (0.06)	0.13
		0.43*** (0.08)	-0.07 (0.09)	0.20
	317 Recursive		0.18*** (0.04)	0.14
		0.36*** (0.08)	0.03 (0.05)	0.19
Wholesale 1921–1939	418	0.17*** (0.03)		0.13
	395 Full-Sample		0.23*** (0.04)	0.14
		0.11* (0.06)	0.13* (0.07)	0.15
	326 Recursive		0.14*** (0.02)	0.17
		0.18*** (0.05)	0.04 (0.03)	0.19

Notes: $\dot{y}_{i\tau}$ is the output growth rate in country i and year τ and $\pi_{i\tau}$ is the inflation rate averaged over 4-quarter values. $\hat{\beta}_\pi$ is the coefficient on inflation; $\hat{\beta}_u$ is the coefficient on unexpected inflation. Each system contains country-specific intercepts α_i. There are 26 countries with retail price data and 24 countries with wholesale price data. Recursive forecasts use a 2-year start-up period. Brackets contains heteroskedasticity-consistent standard errors. On coefficients, p-values less than 0.01 are denoted ***, those less than 0.05 are denoted **, and those less than 0.10 are denoted *.

Table 5: Robustness Checks

(a) slope change at zero inflation

$$\dot{y}_{i\tau} = \alpha_i + (\beta_\pi + \delta d_{i\tau})\pi_{i\tau} + \epsilon_{i\tau}$$

Retail			Wholesale		
$\hat{\beta}_\pi$ (se)	$\hat{\delta}$ (se)	R^2	$\hat{\beta}_\pi$ (se)	$\hat{\delta}$ (se)	R^2
0.22***	0.14	0.14	0.07	0.18**	0.14
(0.08)	(0.19)		(0.04)	(0.07)	

(b) non-linear monotone relationship

$$R[\dot{y}_{i\tau}] = \alpha_i + \lambda_\pi R[\pi_{i\tau}] + \epsilon_{i\tau}$$

	Retail		Wholesale	
	$\hat{\lambda}_\pi$ (se)	R^2	$\hat{\lambda}_\pi$ (se)	R^2
Fixed effects	0.34***	0.17	0.37***	0.17
(α_i)	(0.05)		(0.05)	
Spearman	0.30***	0.09	0.35***	0.12
($\alpha_i = \alpha$)	(0.05)		(0.05)	

(c) quadratic in inflation

$$\dot{y}_{i\tau} = \alpha_i + \beta_\pi \pi_{i\tau} + \gamma_\pi \pi_{i\tau}^2 + \epsilon_{i\tau}$$

Retail			Wholesale		
$\hat{\beta}_\pi$	$\hat{\gamma}_\pi$	R^2	$\hat{\beta}_\pi$	$\hat{\gamma}_\pi$	R^2
0.29***	-0.001	0.14	0.17***	-0.0015	0.13
(0.06)	(0.01)		(0.03)	(0.001)	

Notes: $\dot{y}_{i\tau}$ is the output growth rate in country i and year τ, $\pi_{i\tau}$ is the inflation rate averaged over 4-quarter values, and α_i are country-specific intercepts. There are 26 countries with retail price data (and 411 observations for 1922–1939) and 24 countries with wholesale price data (and 418 observations for 1921–1939). In case (a) $d_{i\tau} = 1$ for deflations and 0 otherwise. In case (b) $R[x]$ denotes the rank of statistic x. Brackets contains heteroskedasticity-consistent standard errors. On coefficients, p-values less than 0.01 are denoted ***, those less than 0.05 are denoted **, and those less than 0.10 are denoted *.