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Unit roots and structural breaks in North American unemployment rates

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Abstract

This paper examines the univariate time-series properties of the unemployment rate in Canada, Mexico, and the United States. Tests are employed that allow for endogenously determined break dates and the results are compared to stationarity tests that assume no break in the data. The structural break unit-root tests contradict the findings of the standard tests. We conclude that North American unemployment rates are trend stationary around a breaking trend. © 2001 Elsevier Science Inc. All rights reserved.

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1. Introduction

A task undertaken by many macroeconomists is to provide forecasts of the unemployment rate. Typically, the forecaster specifies an ARIMA model based on some variant of the Box-Jenkins technique. A model may examine the first difference, or change, in the unemployment rate, or the focus may be on the level of the unemployment rate. The choice of whether to specify the model in first differences or in (possibly, detrended) levels depends on the underlying data-generating process, that is, on whether or not the series is trend-stationary or difference-stationary.[1]

Recently, Payne, Ewing, and George (1999) suggested that for forecasting most U.S. state

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unemployment rates using the first difference is appropriate, as most state unemployment rates contain unit roots. Their paper provides an in-depth study of the time series properties of state unemployment rates and, while their data suggest that the aggregate U.S. unemployment rate is also difference-stationary, others have argued that the aggregate rate is actually a trend-stationary process [e.g., Nelson and Plosser (1982), Blanchard and Summers (1987)]. This paper examines the univariate time series properties of the unemployment rates of the U.S., Canada, and Mexico using several unit-root testing procedures—which also allow for a possible endogenously determined break point.

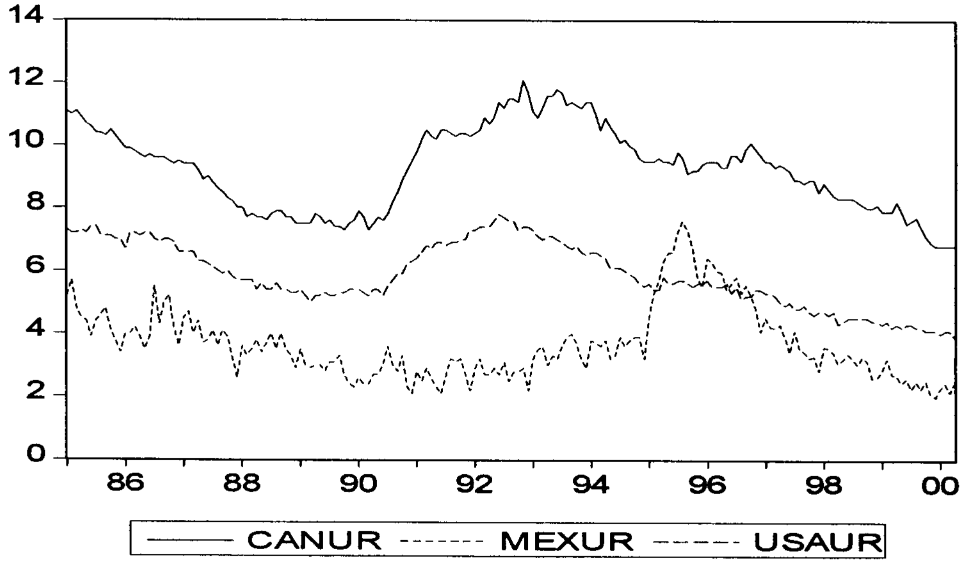
The distinction between a trend-stationary process (TSP) and a difference-stationary process (DSP) is essential for the proper specification of forecasting models. Problems arise when the researcher uses the inappropriate method in attempting to obtain stationarity. In particular, differencing a trend-stationary process may introduce a noninvertible unit-root process, while subtracting a deterministic time trend from a difference-stationary process does not result in a stationary process, since the stochastic trend is still present. Moreover, the two data-generating processes respond differently to shocks. The difference-stationary process has long memory so that shocks are permanent, that is, the series will not converge to the unconditional mean of the series. Shocks to a trend-stationary process are temporary, often characterized as short memory. Shocks will disappear and the series will revert back to its long-run mean.

An important issue addressed in this paper is whether or not a structural break is present in the data that might have changed or altered the underlying data-generating processes of the unemployment rates. Generally speaking, Perron (1989) shows that in the presence of a structural break, standard unit-root tests are biased toward the nonrejection of a unit root. In this case, the forecaster would likely conclude incorrectly that a series had a unit root (when it actually did not), possibly introducing the problem of spurious regression. In a related paper, Arestis and Mariscal (1999) examine the unemployment rates of 26 OECD countries using quarterly data over 1960–1997. Allowing for up to two endogenously-determined break dates, they find breaks in Canada about 1981 and 1990, about 1987 and 1993 for Mexico, and about 1970 and 1984 for the United States. They find only weak evidence of trend stationarity for Mexico and conclude that both Canada and U.S. unemployment rates have unit roots. For most of the other countries in their study, however, the trend-stationary process is determined to be the data-generating process.

From a theoretical point of view there are many potential sources of structural breaks. Events such as oil crises, changes in central bank operating procedures, changes in real interest rates, or major policy changes (e.g., imposition of a free trade agreement, tax reform, etc.) may lead to a break. From a forecasting viewpoint, it is the identification of significant breaks in the data that matters as the proper specification of econometric and time-series models depends on the data-generating process of the unemployment rate series.

2. Data, methodology, and results

The data in this study consist of monthly observations of seasonally adjusted unemployment rates for Canada, Mexico, and the United States over the period 1985:01–2000:04. The



Note: **CANUR, MEXUR, and USAUR denote the unemployment rates for Canada, Mexico, and the United States, respectively.**

Fig. 1. North American unemployment rates.

U.S. unemployment rate is from various issues of the Bureau of Labor Statistics' *Employment and Earnings*. The Canadian data are from *Statistics Canada*.[2] The unemployment rate for Mexico was provided by Edward Yardeni of Deutsche Bank Securities, New York. Fig. 1 presents a plot of the unemployment rates. Panel A of Table 1 provides descriptive statistics for the unemployment rate series over the full sample period.[3]

Table 1
Unemployment rate descriptive statistics

Panel A		Canada	Mexico	United States
Full sample	mean	9.2609	3.6748	5.8750
	standard deviation	1.3337	1.1483	1.0236
	n	184	184	184
Panel B				
Pre-break	mean	9.3280	3.4356	6.4395
	standard deviation	1.3884	0.7501	0.7896
	n	100	118	114
Panel C				
Post-break	mean	9.1810	4.1024	4.9557
	standard deviation	1.2691	1.5525	0.6114
	n	84	66	70

Note: The full sample period is 1985:01-2000:04. The endogenously determined break dates were April 1993 for Canada, October 1994 for Mexico, and June 1994 for the United States. Sample size is denoted by n.

The empirical analysis begins by conducting two commonly used stationarity tests to determine the univariate properties of the unemployment rate series. The augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit-root testing procedures are used for this purpose [Dickey and Fuller (1981), Phillips and Perron (1988)]. Information about the underlying data-generating process of time series has implications for the specification of models often used in forecasting, so these types of tests are often performed prior to specifying the forecasting model. However, Perron (1989) and others argue that the ADF and PP tests are biased toward the nonrejection of a unit root in the presence of a structural break, and unit-root tests which do not allow for this possibility under the null will have low power. Thus, we conduct structural-change unit-root tests in addition to the other tests, and compare the findings.

The time series properties of the individual variables may be assessed by conducting the ADF and PP stationarity or unit-root tests. A time series containing a unit root follows a random walk and requires first-differencing to obtain stationarity, and is said to be first-order integrated, I(l). A variable that is stationary in level form is integrated of order zero, I(0). The augmented Dickey-Fuller (ADF) test to check for the presence of unit roots is conducted by estimating Eq. (1) via ordinary least squares regression:

$$\Delta u_t = \rho_0 + (\rho_1 - 1)u_{t-1} + \rho_2 t + \sum_{j=1}^{m} \beta_j \, \Delta u_{t-j} + e_t \tag{1}$$

where u is the individual unemployment-rate series under investigation, Δ is the first-difference operator; t is a linear time trend, e_t is a covariance-stationary random error and m is determined by Akaike's information criterion to ensure serially uncorrelated residuals. The null hypothesis is that u_t is a nonstationary time series and is rejected if $(\rho_1 - 1) < 0$ and statistically significant.[4] Finite-sample critical values for the ADF test developed by MacKinnon (1991) are used to determine statistical significance.

The distribution theory supporting the Dickey-Fuller tests assumes that the error terms are statistically independent and have constant variance. Phillips and Perron (1988) proposed an alternative unit-root test which allows for a weaker set of assumptions concerning the error process. The Phillips-Perron (PP) test allows for the presence of dependence and heterogeneity in the error term and is based on the least squares estimation of (2):

$$u_t = \alpha + \beta(t - T/2) + \rho u_{t-1} + \nu_t \tag{2}$$

where u is the particular unemployment-rate series, (t − T/2) is a time trend, T is the sample size and v is the error term. The null hypothesis is that u is nonstationary, H_0: $\rho = 1$. If the null hypothesis is not rejected, then this implies that u contains a unit root and is first-difference stationary. A rejection of the null implies that u is a trend-stationary process. The lag structure embedded in the Phillips-Perron test statistics is chosen to match that in the autocovariances of the residuals under the null hypothesis. The finite-sample critical values for the unit-root test developed by MacKinnon (1991) are used to determine statistical significance. Phillips and Perron provide the derivation of the test statistic.

Table 2 presents the results of the ADF and PP unit-root tests for the three unemployment-

Table 2
Unit root tests

Panel A: Augmented Dickey-Fuller	Levels	First-differences
Canada	−1.0967	−4.2983*
Mexico	−1.7082	−8.1104*
United States	−0.7211	−4.1950*
Panel B: Phillips-Perron	**Levels**	**First-Differences**
Canada	−0.8923	−12.3898*
Mexico	−2.4474	−17.0619*
United States	−0.4232	−15.7329*

Notes: * denotes significant at less than the 1 percent level. Significance is based on MacKinnon (1991) critical values. The critical value associated with the 1% level of significance is −3.47.

rate series of North America. The ADF tests and the PP tests all suggest that each of the unemployment-rate series follows a random walk. In particular, each series is integrated of order one, I(1), and requires first-differencing to render a stationary series. Based on these findings, ARIMA-type forecasting models of Mexican, Canadian, and U.S. unemployment rates should be specified in first differences. Moreover, these results suggest that shocks to the respective series are permanent as the series is moved to a new equilibrium level. This finding is not consistent with traditional views of macroeconomists embedded in many Keynesian and sticky-price models in which shocks to aggregate variables such as real output and employment have a temporary effect. In this view, a shock to the unemployment rate should die out as the economy returns to the potential output level associated with full employment and a natural rate of unemployment. The finding of a unit root is in line with models in which shocks have permanent effects such as many real-business-cycle models and some supply-side interpretations of the business cycle.[5]

The time period studied was characterized by a number of *major* economic events. For example, Mexico experienced the Peso crisis in the mid-1990s, the Federal Reserve Bank of the U.S. conducted a number of unanticipated or more/less than expected monetary policy changes (e.g., summer of 1994 and the fall of 1998), the North American Free Trade Agreement went into effect in 1994, and the financial markets of each of the countries may have been rocked by the Asian crisis of 1997, to name just a few. Additionally, the mid-to-late 1990s was a period in which both the U.S. and Canada experienced real economic growth in what appears to have been an investment-led expansion and may be best remembered as the period of the "new" economy. Thus, it is quite possible that a structural break may have occurred in the unemployment-rate data during the sample period.

In order to determine if a structural break did, in fact, occur and whether or not the break was a significant factor in terms of determining the data-generating process, we consider the following regression.

$$u_t = \mu + \theta DU_t + \beta t + \gamma DT_t + \delta D(TB)_t + \alpha u_{t-1} + \sum_{j=1}^{k} c_j \Delta u_{t-j} + e_t \tag{3}$$

where $D(TB)_t = 1$ at $t = TB + 1$ and 0 otherwise; $DUt = 1$ if $t > TB$, 0 otherwise; $DT_t = t$ if $t > TB$, 0 otherwise; and TB is the time of the break. Under the null hypothesis we have

Table 3
Unit root test results with endogenously determined structural break

	μ	θ	β	γ	δ	α	TB
Canada	0.1240	−0.1269	0.0025	−0.0039	0.4494	0.9732	1993:04
	(0.89)	(−1.89)	(3.32)	(−2.64)	(2.14)	(65.29)	
Mexico	0.8283	0.8101	−0.0016	−0.0156	−0.4913	0.7781	1994:10
	(3.98)	(3.89)	(−1.14)	(−4.18)	(−1.08)	(17.05)	
United States	0.1524	−0.0891	0.0005	−0.0010	0.0031	0.9703	1994:06
	(1.39)	(−2.02)	(1.24)	(−0.91)	(0.98)	(57.57)	

Notes: TB is the endogenously determined break date. t-values are in parentheses. The null hypothesis is that the series has a unit root and is rejected if α is significantly less than one. Critical values for the unit root with structural break test are available in Perron (1994). The critical value associated with the 1% level of significance is −4.88.

the restrictions $\alpha = 1$ and $\beta = \gamma = 0$. Under the alternative hypothesis of a "trend-stationary process about a breaking trend" we expect $\alpha < 1$, $\theta \neq 0$, $\beta \neq 0$, $\gamma \neq 0$. In econometrics terminology, this model is of the "innovational outlier" type and both the intercept and the trend coefficient are allowed to change after the time of the break.

Perron (1989) developed an estimation strategy for cases in which the break date is known a priori. One estimates Eq. (3) using ordinary least squares and chooses the lag length k to eliminate autocorrelation in the residuals. The selection of the truncation-lag length k may be determined via standard methods such as the general-to-specific method described in Perron (1989) and the more common minimum AIC method. The structural-break unit-root testing procedure developed by Perron (1989) assumes that the data are uncorrelated with the break point, but Christiano (1992) and others have criticized this assumption since the choice of break point is based on prior observation of the data and is therefore subject to the problems associated with "pretesting" [Zivot and Andrews (1992)]. The view that a "break-causing" event is endogenous—as opposed to exogenous—is considered by Zivot and Andrews (1992), Perron and Vogelsang (1992), and Perron (1994). Since it is difficult, if not impossible, to know a priori the precise date of a break, we treat selection of the break point as the outcome of an estimation procedure. In what follows, we use the procedure outlined in Perron (1994) to test the null hypothesis of an integrated process allowing for a possible change in the level and the trend.

The strategy is to estimate Eq. (3) while allowing both the break point and the lag length on the autoregressive term to vary endogenously. The endogenously determined break point is then selected as the date, over all possible break points, which minimizes the t-statistic for testing $\alpha = 1$ in Eq. (3). Perron (1989, 1994) and Zivot and Andrews (1992) provide the critical values for the test. The selection of the truncation-lag length k is determined in the same manner as in the exogenous-break-date case.

Table 3 presents the results of the stationarity tests allowing for the break date to be endogenously determined. Our evidence suggests that each unemployment-rate series is a trend-stationary process about a breaking trend. The break date for the United States is June 1994 and for Mexico it is October 1994. The break date for Canada is April 1993.

The finding of trend stationarity is contradictory to the results from the standard augmented Dickey-Fuller and Phillips-Perron unit-root tests. Furthermore, we find a significant mean shift in each country's unemployment rate, with a downward shift in the U.S. and Canada and an upward shift in Mexico. The structural-break unit-root tests imply that shocks to the unemployment rates of North American countries die out and are temporary in nature. This is in line with earlier findings for the U.S. of Nelson and Plosser (1982) and provides evidence in favor of the traditional sticky-price and Keynesian-type macroeconomic models of the business cycle in which shocks are transitory and the unemployment rate is mean-reverting.

Note that the findings presented in Table 3 suggest that the U.S. unemployment rate has a lower mean after the endogenously determined break than before. This result is consistent with Stiglitz (1997) and Gordon (1997), who claim that the natural rate has fallen in recent years. The Canadian unemployment rate also has both a lower mean and lower trend value in the postbreak period. Canada's natural rate appears to have fallen as well. In contrast, Mexico is characterized by an upward shift in mean, although with a lower trend value than before the break. The higher mean may suggest that jobs were eliminated or have left Mexico since the break, at least from the formal sector. This would be the case if, for example, there was a decline in the nation's level of potential output. Panels B and C of Table 1 show the descriptive statistics for each country in the pre- and post-break periods.

Given that we found contradictory evidence using different unit-root tests, the final step in our analysis is to compare the ADF-regression outlined in (1) to the endogenously-determined structural-break regression in (3).[6] Dynamic in-sample forecasts of the unemployment-rate series were conducted, and in each case the root-mean-square error (RMSE) for the structural-break model was smaller than that generated by Eq. (1). Thus, in the view of the evidence that each unemployment-rate is stationary around a breaking trend, the structural-break model appears to be a better specification of the unemployment rate.

3. Possible links to NAFTA

This paper stresses the importance of determining the underlying data-generating process before constructing forecasting models of such macroeconomic variables as the unemployment rate. The unemployment rates of Canada, Mexico, and the U.S. were tested for the presence of unit roots using the popular augmented Dickey-Fuller and Phillips-Perron tests, the results of which suggest that each series is a difference-stationary process. It is, however, well-known (Perron (1989)) that structural breaks bias test results in favor of unit roots even when they are not present. It is important, therefore, to ensure that structural breaks in the series have been properly accounted for.

Since the period examined encompasses a variety of major economic events that could have been sources of structural breaks, we examined the unemployment-rate series using a unit-root testing procedure capable of accounting for such breaks. The structural break model provides for endogenous determination of the break date. The results obtained in this way contradict the earlier conclusion that the unemployment rates have unit roots. We conclude that each unemployment-rate series is trend-stationary around a breaking trend. The findings in turn suggest that shocks have only temporary effects on unemployment.

One particularly interesting finding is that the break dates all occurred within a relatively close span of time, in fact, within eighteen months of one another. In particular, the unemployment rates of Canada, Mexico and the United States each experienced a break in the period between April 1993 and October 1994. Among the events which occurred during that period, many might be considered to be country-specific. Hence, there would be no reason to expect them to occur close to each other, unless there was a single, significant common event. One such event was the North American Free Trade Agreement, signed in January 1994. Of course, one would not necessarily expect the break date to coincide precisely with the date of Congressional passage of NAFTA; rather, the break would be expected to occur somewhat before that date if agents acted rationally on their expectations that NAFTA would pass or after the date if agents in the labor market expected implementation lags.

While the endogenously determined structural-break unit-root tests are capable of determining the date of a break, they are incapable of determining the precise source of the break. However, it is possible that NAFTA may have had a structural-break effect on the unemployment rates of Canada, Mexico, and the U.S. by disrupting or changing labor markets in some significant way. Certain provisions in the agreement may have increased labor-market uncertainty, altered incentives to migrate, and/or affected some region's or industry's productivity relative to another. Examining wages in Mexico and the United States, Robertson (2000) finds evidence that the linkage between these labor markets may indeed have been altered by NAFTA. He shows that the typical response to labor-market shocks is for wages to return to an equilibrium differential, which suggests that the cross-border wage-adjustment process is trend-stationary. He finds further that the pace of wage convergence slowed down after NAFTA. Our results regarding changes in trend are consistent with that finding. Moreover, the shifts in means are consistent with Robertson's contention that migration is an important mechanism integrating North American labor markets.

4. Concluding remarks

Generally speaking, this paper has important implications for our understanding of how the labor markets of Canada, Mexico, and the United States behave. In terms of the theoretical modeling of the macroeconomy, our findings are more in line with sticky-price and Keynesian models that imply an equilibrium unemployment rate and a corresponding full employment level of output that the economy tends to gravitate toward. Clearly, however, there may be shifts in the aggregate supply curve or changes in the production capabilities of the economy that would tend to alter the level of potential output and the equilibrium unemployment rate. If these shifts are not accounted for in the empirical analysis it is quite possible that one would misinterpret the information provided in the unemployment-rate time series. In other words, neglecting to account for the presence of structural breaks in the unemployment-rate series may lead to a vastly different and erroneous conclusion. Any policy that relied upon accurate forecasts and/or an accurate understanding of the unemployment rate could then be misconstrued. Accounting for the possibility of such breaks, we find that each unemployment rate is a mean-reverting process. Thus, there is a tendency for the unemployment rate to return to an equilibrium value or natural rate following macroeconomic shocks. Our results imply that the proper specification of empirical models of the unemployment rate should be in levels and not first differences and illustrate the importance of considering structural breaks when testing for unit roots.

Notes

1. Under the trend-stationary hypothesis a time series x = c(+d) whereas under the difference-stationary hypothesis x = s + c(+d), where c denotes a stationary component, d a deterministic trend, s a stochastic trend, and parentheses indicate that the inclusion of d is allowed but not required. The distinction between the two hypotheses rests on whether or not a stochastic trend is present. It is not enough to remove the deterministic trend in order to render a difference-stationary process stationary. However, if d is present in a trend-stationary process, then the series must be "detrended" by removing the deterministic function of time.
2. We are grateful to Christian Zimmerman for providing the Canadian data.
3. An important point to note is that these are official unemployment rates. Mexico may have a larger and more significant informal sector as a share of total employment than either the U.S. or Canada. If that is the case, the Mexican unemployment rate may understate actual unemployment.
4. There are actually two other hypotheses that can be tested using Eq. (1). The series contains a unit root with drift, but without a time trend (H_{02}: $\beta = 0, \rho = 1$). The series contains a unit root without drift and without a time trend (H_{03}: $\alpha = 0, \beta = 0, \rho = 0$). Our findings, reported below, were robust to the specification of the null.
5. Romer (1996) provides detailed explanations of the types of macroeconomic models mentioned here.
6. Results comparing Eq. (2) to Eq. (3) were similar.

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