Available online at www.sciencedirect.com
SCIENCE DIRECT
European Journal of Political Economy
Vol. 20 (2004) 447–461
European Journal of POLITICAL ECONOMY
www.elsevier.com/locate/econbase

Decomposing violence: political murder in Colombia, 1946–1999

Jurgen Brauer[a,*], Alejandro Gómez-Sorzano[b], Sankar Sethuraman[c]

[a] College of Business Administration, Augusta State University, 2500 Walton Way, Augusta, GA 30904, USA
[b] Department of Economics, University of Colorado at Boulder, 256 UCB, Boulder, CO 80309-0256, USA
[c] Department of Mathematics and Computer Science, Augusta State University, 2500 Walton Way, Augusta, GA 30904, USA

Received 7 June 2002; received in revised form 15 May 2003; accepted 14 June 2003

Available online 28 March 2004

Abstract

We apply the Hodrick–Prescott (HP) and Beveridge–Nelson (BN) business cycle decomposition methods to a time series of homicides in Colombia (1946–1999). Separating out "permanent" from "cyclical" murder, we hypothesize that the cyclical part coincides with the periodic political unrest in the country. The results show a good match between the political events in the country and the computed cyclical murder component.

JEL classification: C22; D74; O54
Keywords: Colombia; Homicide; Beveridge–Nelson; Hodrick–Prescott; Business cycle; Terrorism

1. Introduction

The countries of Latin America record, by far, the highest homicide rates in the world, averaging 20–30 murders per 100,000 people, i.e., two to three times as many as the next most violent regions of the world (Guerrero, 1998; Londoño, 1998, p. 72). Within Latin America, Colombia is known for its extremely high levels of homicidal violence, resulting in one of the highest murder rates in the world. According to Colombian National Police statistics, homicides increased from around 5000 per year in the 1950s and 1960s to about 10,000 per year by 1980 and to about 25,000 per year by

* Corresponding author.
E-mail address: jbrauer@aug.edu (J. Brauer).

0176-2680/$ - see front matter
doi:10.1016/j.ejpoleco.2003.06.003

1990 (Fig. 1). A further surge to nearly 30,000 murders per year was seen in the early 1990s. This has moderated somewhat but, in absolute numbers, still hovers between 20,000 and 25,000 per year.

When adjusted for population growth, i.e., homicides per 100,000 people in the population, a similar pattern emerges. A rapid per capita murder increase occurred from 1946 to the late 1950s, followed by a 10-year period of sustained murder reductions (Fig. 1). This downward trend reversed in the 1970s and then shows exactly the same pattern as for the absolute numbers. The country's murder rate varies substantially not only over time, but also from region to region (e.g., Dinar and Keck, 1997, pp. 9–10; Guerrero, 1998, pp. 96–97; Londoño, 1998, p. 76), with rates as low as 16/100,000 (nearly "normal" as compared to the rest of the world) to rates as high as 900/100,000 in the city of Apartado (Guerrero, 1998, p. 97).

Frightful as the absolute and population-adjusted numbers are, they underestimate the truth. Following a survey, Rubio (1998a, p. 606) writes that even for murder "more than half of the households victimized stated that they had 'not done anything,' and only 38% reported that they had made a formal complaint" to the authorities. Incredibly, by comparing separate statistical reporting by the police and by the justice agencies, Rubio finds wide disparities for more than a quarter of Colombia's municipalities. The disparities are largest in municipalities characterized by the presence of any armed force (military, paramilitary, drug gangs, guerrillas; Rubio, 1998a, p. 607). Apparently, victims' families fear reprisals.

Without doubt, Colombia's murderous violence is related to two of its most salient features, the drug trade and its civil war, that have marred the country for decades. Less well known and appreciated is that these two factors account only for a portion of all murders in the country (Guerrero, 1998, p. 98). For murder, the primary risk factors are alcohol consumption, possession of firearms, and weekends. For example, a quarter of all murders take place on Sundays, more than half on Friday, Saturday, and Sunday, with disproportionate increases on holidays. Most murders are patently nonpolitical, take place

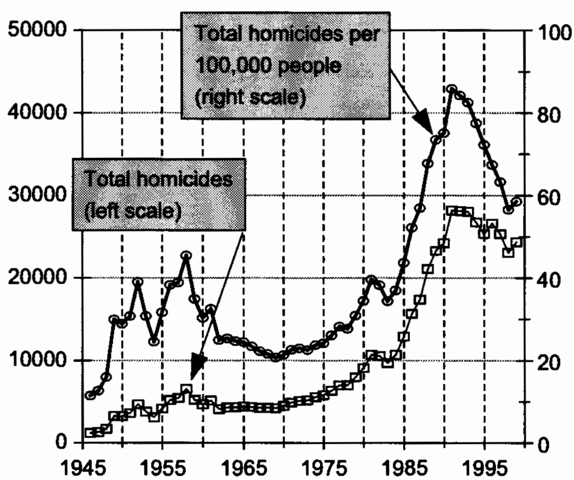


Fig. 1. Total homicides, Colombia, 1946–1999.

at night, in urban areas, are committed by poor people on poor people, and alcohol is frequently found in the victims (Londoño, 1998, p. 75). However, Guerrero (1998, p. 98) observes that while alcohol consumption might explain the high levels of murder it cannot explain the drastic murder increase in Colombia in the 1980s and 1990s.

Also contrary to popular perception, several studies have failed to establish links between murderous violence and poverty rates, unemployment rates, urbanization rates, or rates of economic growth (Londoño, 1998, p. 74; Guerrero, 1998, p. 97). Indeed, Rubio (1997) and others have made persuasive arguments according to which the educated and uneducated classes both engage in criminal and violent activity for the simple reason that crime pays well. Income and education are no longer linked, but income and crime are (Rubio, 1997, p. 812). Average annual incomes from crime have been variously estimated at up to $70,000 per person, a huge premium over Colombia's per capita 1995 GDP of around $1800 (Bejarano, 1997, p. 12). The breakdown of Colombia's justice system also encourages criminal and violent behavior as the probability of being caught, tried, and convicted is becoming smaller over time. By 1994, convictions rates had dropped to below 4% (Rubio, 1998a, p. 606), and sentences rarely exceeded 6 months of jail time (Rubio, 1998b, p. 91).

There is widespread agreement among analysts that Colombia's violence is costly, both at the microeconomic level (e.g., Dinar and Keck, 1997) and at the macroeconomic level, estimated at up to 15% of GDP (Bejarano, 1997, p. 10). There also is evidence that major perpetrators of violence—the military and paramilitary forces, the drug traders, and the various guerrilla groups—act in semicollusive fashion to keep the spoils of war going (Richani, 1997), evidence almost perfectly in line with the theory suggested by Brito and Intriligator (1992).

While ongoing research will have to identify and disentangle the various causes and possible intervention mechanisms of extreme, generalized violence in Colombia, our concern in this paper is much more narrow and limited. On the hypothesis that political unrest and politically motivated murder are cyclical, we apply business cycle decomposition methods to the murder time series and then compare the estimated (quantitative) cyclical or "transitory" component to a narrative (qualitative) account of cycles of political violence in Colombia. We find a good overlap between our estimates of turning points in the cycle and the narrative of the country's political ups and downs; when the political context suggests much unrest, the cyclical component of murder increases, and vice versa. The trend or "permanent" component of the series is interpreted as that part of the murder time series that would have occurred without political violence.

The research reported here is a pure time series study. We make no claim as to the magnitude of "political" murder, but we do suggest that we may have found a way to gauge turning points in the "political" murder cycle. Especially for countries facing domestic terrorism, this would be an important advance, possibly permitting real-time assessment of whether a country finds itself in a cyclical murder upswing or downswing. Once the time series is separated into "political" and "nonpolitical" murder, further research can build underlying structural models for each part of the series.

The next section presents a discussion of the data and the decomposition methods employed. This is followed by the interpretation of our findings, i.e., the matching of the cyclical component to the political narrative. The final section concludes.

2. Data and methods

The Colombian National Police has a record of crime statistics that reaches back to 1946 (various issues of Revista Criminalidad). The statistics distinguish among 14 types of crime. Type number 13 (crimes against life and person) contains some 20 categories such as murder, abortion, and personal injury. The murder categories are murder (homicidio) and aggravated murder (homicidio agravado). Since 1993, there is also an attempt to separate out further types of murder, namely murder with terrorist intent (homicidio con fin terrorista) and death associated with the exercise of official police duties (homicidio con función, razón cargo o ejercicio de sus funciones). For our analysis, we use the number of murders for these four categories combined; that is, we collapse all these categories of murder into a single group.[1]

Time series can be broken into constituent components. Because we use annual data, the seasonal component does not apply to our case. The long-run trend component is often simply modeled as a linear or nonlinear trend line over time, and the cyclical component is the remaining variation around this trend. We apply the Hodrick and Prescott (1997) and the Beveridge and Nelson (1981) decomposition techniques.

2.1. Hodrick–Prescott

Without going into any detail here, none of a variety of simple time trend, moving average, and exponential smoothing techniques are appropriate for our purpose.[2] For business cycle research, a popular method to smooth a time series and produce its long-run trend component is the Hodrick–Prescott (HP) filter (1997). Technically, consider

$$\sum_{t=1}^{T}(y_t - s_t)^2 + \lambda\sum_{t=2}^{T-1}((s_{t+1} - s_t) - (s_t - s_{t-1}))^2, \qquad (1)$$

where y is the original series, t is time ($t = 1,\ldots,T$), and s is the smoothed series. The filter produces the smoothed series by minimizing Eq. (1) whose first term denotes the squared difference between an original and its smoothed value at time t (i.e., the variance) and whose second term defines upper and lower bounds of s, where $\lambda = 0$ returns the original series and $\lambda \to \infty$ produces a linear smoothed series. Because we deal with annual data, we use the recommended default value of $\lambda = 100$. E-Views 4 contains a Hodrick–Prescott routine that produces the relevant smoothed trend estimates which, along with the original

[1] If one were to request to reexamine police or justice records in order to classify them case by case into "political" or "nonpolitical" murder categories one would, in Colombia, write one's own death sentence as one of the paper's authors attests (also see Giraldo, 1996; Kirk, 2003). In such cases, our approach of time series decomposition may be the only feasible alternative to get a statistical handle on political murder.

[2] We nonetheless applied the single, double, and Holt–Winter smoothing techniques. In all instances, the estimated series is simply shifted to the right of the original series (all peaks and troughs are right shifted), thereby consistently missing all turning points of the actual homicide series.

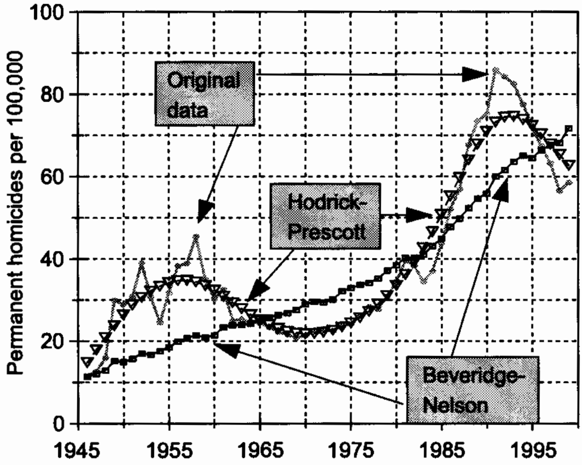


Fig. 2. Original data (total homicides per 100,000 people) and permanent component according to HP and BN methods.

data and the Beveridge–Nelson (BN) results, are displayed in Fig. 2.[3] Deviations from the trend constitute the cyclical component (Fig. 3).

Our hypothesis is that, in Fig. 3, an upward movement of the cyclical component of the homicide time series corresponds to time periods with marked political unrest whereas a downward movement of the cyclical component denotes relative political calm in Colombia. We offer a discussion in the Interpretation of results section.[4]

2.2. Beveridge and Nelson

In 1981, Beveridge and Nelson (BN) introduced a new business cycle decomposition technique. The objective was to produce a technique with superior turning point performance. Because the estimation of data points in time t completely relies on past values, $t-1$, $t-2$,. . .,$t-n$, BN describe their method as a "real-time" technique; plug new data points into the model as data become available, and it will tell you whether the

[3] In E-Views, double-click on the original data series icon, click on Procs, select Hodrick–Prescott Filter, and type in the desired smoothing parameter, λ, or accept the default value $\lambda = 100$. To test the robustness of the resulting series, we varied the smoothing parameter drastically but did not obtain materially different results. For example, according to Ravn and Uhlig (2002), the optimal smoothing parameter should be between 6.25 and 8.25 for annual data, not 100. We used those values, as well as 20, 40, 60, 80, and 800, in addition to the default value of 100. With 54 observations, runs for eight different smoothing parameters result in eight series of estimates with a total of 432 data points. With a mere handful of exceptions, the 432 data points in the eight estimated series of cyclical murder result in identical turning points, and it is the turning points, not the magnitudes of the estimates, that interest us. See Maravall and del Río (2001) for a discussion of the filter default values. On problems with the mechanical application of the Hodrick–Prescott filter, see Harvey and Jaeger (1993).

[4] There are of course no "negative" murders in Fig. 3. The negative numbers represent homicides falling below the trend line. In our interpretation, it is the lack of political unrest that accounts for below-trend homicides.

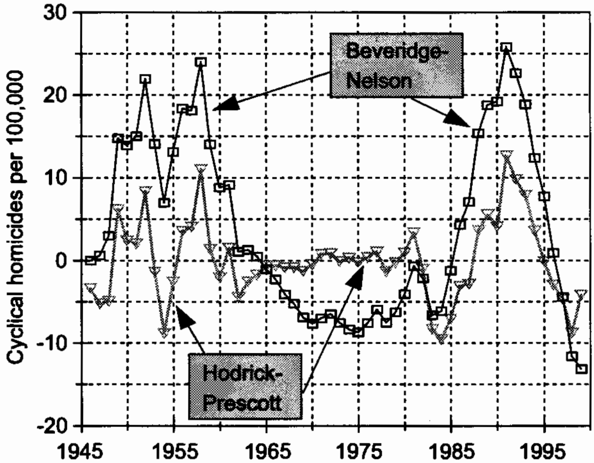


Fig. 3. Cyclical component according to HP and BN methods.

business cycle is turning. The technique requires to first fit an ARIMA model on the first-differenced natural logs of the dependent variable. Because in the spirit of BN we do not propose any structural model explaining the data movement, nor propose to engage in any forecasting of the data points, we conducted an unabashed best fit search which resulted in an ARIMA(0,1,13) model with moving average terms at lags 1, 5, and 13. The results are:

d(lthompc) =	c	+ ma(1)	+ ma(5)	+ ma(13)
Coefficients	0.0324	0.2569	− 0.4911	− 0.5376
t-stats	3.2710	3.2132	− 5.7861	− 5.8794
p-values	0.0005	0.0023	0.0000	0.0000
Adjusted R^2 = 0.1024; DW = 2.0445; F = 2.9780; p-value(F) = 0.0404				

where d(lthompc) is the first difference of the natural log of total homicides per 100,000 persons in Colombia, 1946–1999. Estimating this model minimized the Akaike Information Criterion (AIC) as well as the Schwartz Criterion (SC). We ran the model with RATS 4 as well as with E-Views 4 and, except for rounding, obtained the same estimates.[5]

[5] E-Views and RATS use different implementations of the Schwartz Criterion (SC). E-Views works off the log likelihood function, whereas RATS works off the sum of squared residuals. We confirmed both formulas by hand computing the respective criterion to check the computer printouts. Running a variety of ARIMA models, the model with moving average model with lags at 1, 5, and 13 returns the lowest SC in E-Views and RATS, respectively. (RATS does not report the AIC).

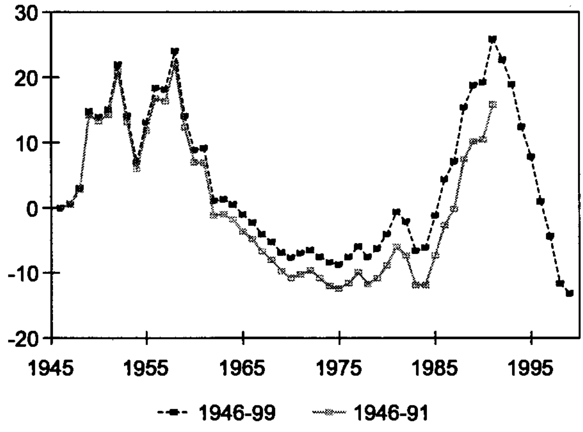
Once a model that best fits (or reproduces) the original data is estimated, the permanent and cyclical components can be extracted from the estimated data points. The resulting data are displayed in Figs. 2 and 3.[6] [7] [8]

3. Interpretation of results

It would appear that the Hodrick–Prescott (HP) and Beveridge–Nelson (BN) methods yield substantially different permanent trend information (Fig. 2). However, both result in comparable estimates of the cyclical movement (not in magnitude but in turning points), at

[6] Neither E-Views nor RATS contains a Beveridge–Nelson routine (a user-supplied routine is available on the RATS web site at http://www.estima.com). Using the original BN (1981) method, the extraction of permanent and cyclical components from the original series is computationally very intense. Cuddington and Winters (1987), Miller (1988), and Newbold (1990) provide computationally easier methods. In his dissertation, Cárdenas (1991) provides an exceptionally easy and conceptually appealing way to compute the components, and that is the method we apply. Because we failed to locate a published account of Cárdenas' method, we provide the mathematical details in Appendix A. To ensure correctness, we computed the permanent and cyclical components by BN's original method, by the Cuddington/Winters method, and by the Cárdenas method, using the first actual observation as the initial value. All three methods resulted in identical estimates.

[7] One reader observed that if the BN method was run for a different time period, say 1946–1991, instead of 1946–1999, the estimates of the permanent and transitory components would change. This is true and changes the estimated magnitudes (we reran the underlying ARIMA which also is (0,1,13) with MA lags at 1, 5, and 13) but does not change the turning points at all (see figure below). Our interpretation thus remains entirely unchanged.



Colombia's estimated cyclical murder for different periods

[8] We also ran the BN procedure on the homicide and aggravated homicide subseries (available since 1959) and came up with nearly identical turning points. The BN permanent component in Fig. 2, incidentally is not linear. Fitting a linear or quadratic regression to the permanent component data for instance leaves positive autocorrelation in the error terms. Instead, the permanent component is a random walk with the same drift as the original data, plus an innovation proportional to the original data. For mathematical details, contact the authors.

least for the early (up to 1965) and the late years (as from 1980) of the series. From 1965 to 1980, the HP method tracks the actual data almost without deviation because there is nothing to be smoothed in the original data series. In contrast, the BN method produces cyclical information throughout the entire time period. (HP is a smoothing technique whereas BN is a trend extraction technique.) We therefore focus here on interpreting the political events of Colombia in light of the BN cyclical component we extracted from the data series. The chronology and event description is taken from Bushnell (1993).[9]

It appears, in Fig. 3, that there are three major periods in the cyclical component of murder in Colombia. The first occurs from 1946 to 1958, with a short-term decline in the murder rate from 1952 to 1957. The second period occurs from 1958 to the late 1970s. One could also argue that the second period lasts from 1965 to 1985, a 20-year period during which the estimated cyclical ("political") murder lies below the permanent trend line. However, because we cannot be sure about the actual number of murders, which depends on the quality of record keeping, it is best to focus on turning points and movements, rather than magnitudes, of the series. The third period occurs as from the late 1970s when an upsurge in murder is observed, until the series peaks in 1991. Thereafter the cycle declines once more.

3.1. The first period: 1946–1958

The Conservative Party's Mariano Ospina Perez assumed the country's presidency by election in August 1946. On 9 April 1948, Jorge Eliecer Gaitán, a charismatic Liberal Party presidential candidate was murdered by unknown assailants. This murder initiated a violent outburst in Botogá, the Bogotazo, that began the period commonly known as La Violencia, reflected in the surge of murders tracked in Fig. 3. This period lasted until 1957, a period where political violence primarily, but not only, emerges from the confrontation between adherents to the two major political parties. Following Gaitán's murder, Liberals achieved victory in congressional elections in June 1949, but presidential victory is obtained by the Conservative Party's Laureano Gómez in November 1949. Political violence with leftist guerrillas, who view both the Liberal and the Conservative Party as establishment parties of landowners and other vested economic interests, continued to such an extent that the military took power in 1953 under General Gustavo Rojas Pinilla. This resulted in an initial decrease in the pace of violence (see the decline in Fig. 3 in 1953 and 1954) but picked up in the latter years of Rojas Pinilla's tenure. Murderous violence first declined as killings originated by guerrillas were stopped but then increased as the military began to kill increasing numbers of the guerrillas. Rojas Pinilla's initial success led the national assembly to elect him to a full four-year presidential term in 1954. However, by May 1957, Rojas Pinillas' inability to put an end to La Violencia led to a nationwide general strike. A military junta took control, and Rojas Pinilla went into exile.

[9] The number of possible decompositions of an observed series (homicides) into trend and cycle components is infinite. Whether the extracted cyclical information "matches" the political events in Colombia requires our subjective judgement. We have not found any literature that disagrees with the dating of the country's major political up and downswings.

3.2. The second period: 1958–1978

The military junta yielded to a bipartisan coalition, called the National Front, that remained in control until 1978. The National Front amounted to an agreement between the Liberal and Conservative Parties to trade presidential terms and to adhere to a quota system in the assignment of ministerial and other government posts. This should reduce the amount of murder due to the clash between the parties' adherents, as indeed it did (see the cyclical decline in Fig. 3). The first National Front president was Alberto Lleras Camargo (Liberal). President from 1958 to 1962, he was followed by Conservative Party member Guillermo León Valencia (1962–1966). The third president (1966–1970) was Liberal Carlos Lleras Restrepo (not related to the first Lleras), during whose term murder rates fell to 20/100,000, the lowest since the Bogotazo and almost normal by other countries' standards. The fourth National Front president was Conservative Misael Pastrana Borrero (1970–1974).

Various old and new guerrilla movements, which had been active for several decades, were formalized in the 1960s. The Fuerzas Armadas Revolucionarias de Colombia (FARC) was formed in 1963, the Ejército de Liberación Nacional (ELN) in 1965, the Ejército Popular de Liberación (EPL) in 1967, and the M-19 (Movimiento 19 de Abril) in 1970. The end of the National Front period occurred between 1974–1978, with the presidency of Liberal Alfonso López Michelsen. During his tenure, Colombia experienced considerable economic growth, driven by a commodity export boom (coffee, coal, oil, and marijuana; not yet cocaine). It is generally accepted that Michelsen's administration suffered from widespread corruption and involvement with the emerging drug trade. It is also the period when guerrilla activity takes an upward turn, reflected in Fig. 3 in the cyclical upswing of homicides.

3.3. The third period: 1978–1999

The 20-year period of the National Front ends, as does the relative political calm, when another Liberal wins the presidential election (Julio César Turbay Ayala; 1978–1982). His term of office sees an end to Colombia's economic boom and an upsurge in revolutionary activity. For example, in December 1979, in a dramatic move that made the world's news headlines, the M-19 guerrilla group seized the Embassy of the Dominican Republic in Bogotá and held thirteen ambassadors hostage who had met at the embassy. The hostages included the US envoy. Both the HP and the BN cyclical murder series show an upward movement of murder for the Turbay years (Fig. 3). The next election is won by Conservative Belisario Betancur Cuartas (1982–1986). He begins peace negotiations between government and guerrillas (except with the relatively small ELN). The cyclical component of our series declines in 1982 and 1983, holding even in 1984 (HP shows a further decline in 1984). However, the peace negotiations did not result in guerrilla demobilization and weapons surrender. Instead, in 1985, three presidential candidates were assassinated; moreover, the M-19 occupied the Colombian Justice Palace (the seat of Colombia's Supreme Court) and many judges were murdered. Betancur broke off peace negotiations, and our series shows an uptick in homicides. The period of the greatest number of murders in Colombia is now ushered in.

Liberal Virgilio Barco Vargas, an MIT-trained civil engineer, was elected president (1986–1990). Although a former M-19 member, Bernardo Jaramillo Ossa, founded a new political party, the Unión Patriótica, there is now open violent conflict among government, various guerrilla and paramilitary groups, and—increasingly—drug traffickers as cocaine replaces marijuana and the dollar volume at stake becomes ever larger.

A major break occurs when Liberal César Augusto Gaviria Trujillo (1990–1994) became president and pushed the legislature to adopt a new constitution in 1991 (to replace the constitution of 1886). A priori, there is no particular reason why a mere change in the country's constitution should mark the beginning of the pronounced fall in the cyclical murder series (Fig. 3). However, at age 43, Gaviria was the first person of the post-La Violencia generation to become president, and the new constitution was received to general acclaim across the country, swept up in a spirit of renewed hope for peace. More substantially, Gaviria did appoint a former guerrilla leader to his cabinet and pushed through large-scale increases in the government's social expenditure budget, moves that might be interpreted as accommodating rebel demands and leading to declining "political" (i.e., cyclical) murder. At the same time, the increasing dollar value of the drug traffic may have pushed up the slope of the permanent murder series (Fig. 2), perhaps reflecting entangled political and economic interests.[10] Indeed, Colombian "popular" knowledge across the spectrum of opinion asserts that the administration of Liberal Ernesto Samper Pizano (1994–1998) was "controlled" by the predominant drug cartels (Medellín y Cali), with increasing participation in that trade by the main guerrilla groups. If so, there would be no "need" for political violence which switches to become nonpolitical permanent violence. Another Liberal president, Andrés Pastrana Arango (1998–2002), in fact went so far as to grant in 1999 the largest rebel group, the FARC, a demilitarized zone the size of Switzerland (42,000 km^2) and placed it under the FARCs administrative control. The post-1991 period might be summarized as inclusion (Gaviria), collusive cooption (Samper), and appeasement (Pastrana), all of which would suggest the very decline in cyclical violence we extracted from the data.

3.4. *Colombia's future*

Despite the cyclical decline in murder in the 1990s, a stable collusive arrangement to jointly exploit the country's resources (á la the National Front of 1958–1978) appears not

[10] One might therefore argue that the character of Colombia's "political" violence changed during the 1990s, i.e., that although it was cloaked in terms of revolutionary and counterrevolutionary language, the observed violence is linked to the economics of the drug traffic. Greed takes preference over grievance (Collier, 1999, 2000; Sambanis, 2002), and an attempt at collusive exploitation of the country is made. Revolutionaries and counterrevolutionaries become bandits who defend their respective territories and interests with murder. If this is correct, the war in Colombia in the 1990s was essentially an economic war over access to and exploitation of natural resources, not unlike those we observed in Africa in the 1990s (e.g., Sierra Leone, Liberia, Angola). This war is unlikely to cease unless the major sources of funding—US military aid and US drug purchases—cease. This interpretation, even if correct for the 1990s, is now probably moot as the FARC and Colombia's new president (Álvaro Uribe Vélez, 2002–2006) have openly resumed their war.

possible among the major vested interests—the government and its military units, the paramilitary units, the drug producers, and the various guerrilla groups—and there remains, in our opinion, only the possibility of a renewed surge in political violence and murder. Indeed, Pastrana's appeasement arrangement with the FARC ended in February 2002 as it became clear that it had no intention of keeping a peace that would leave it restricted to only part of the country. Its ideological concerns not having been met, and unwilling to be locked into a limited territory from which to extract financial resources, it has resumed its terrorist attacks on life and property of ordinary Colombians as well as on government property and officials. All sides to the conflict still appear to believe that each can triumph over the others for a larger share of the spoils. As further data points become available, we would expect an upturn in the BN and HP cyclical component of Colombia's murder time series.

4. Conclusions

This paper is, primarily, a statistical exercise to demonstrate how one might get at turning points in (state and nonstate) domestic terrorist activity. Other techniques could be, and will be, tried. It bears repeating, though, that our approach here, in contrast to the political business cycle literature and other approaches, is a pure time series and not a structural regression effort. Our narrow interest is not to match quantitative RHS variables with a quantitative LHS variable. In fact, we do not have an LHS variable unambiguously called "political murder." Instead, the effort here is to create a proxy of such a variable—the cyclical murder component—and to learn if we can match it with the generally accepted political narrative of political events in Colombia. It would appear that we can; the cyclical component of Colombia's homicides strongly coincides with the country's political events.

In future research, we plan to apply other statistical techniques as well as to construct structural models to explain the movement of the permanent and cyclical murder series in Colombia and also to repeat the decomposition exercise with subnational data (i.e., by administrative departamento). Provided that consistently collected figures are available, we believe that an application of the decomposition method is also possible and worthwhile for countries other than Colombia.

Acknowledgements

We thank the Margaret Ann Isely Foundation, Eugenia Almand, and Barbara Bertram for hospitality and office space during a research stay in Denver, CO (March 2002). For assistance with literature search, we thank Matthias Spoerle. For comments on a draft paper we thank participants at international conferences in Berlin, London, and Lisbon (all in June 2002) and for written, constructive comments we thank two anonymous referees as well as Manolis Athanassiou, Thad Brown, Kostas Drakos, Charles R. Nelson, Nadir Öcal, Zacharias Psaradakis, Ron Smith, Jülide Yildirim, and Leonid Zarangas. The usual disclaimer applies.

Appendix A. The Beveridge–Nelson decomposition of a time series

Let w_t be the stationary first differences of a nonstationary series z_t

$$w_t = z_t - z_{t-1} \tag{1}$$

Wold's (1938) decomposition theorem states that

$$w_t = \mu + \lambda_0\varepsilon_t + \lambda_1\varepsilon_{t-1} + \ldots, \text{ where } \lambda_0 \equiv 1 \tag{2}$$

and λ_i are constants and the ε's are uncorrelated errors. BN (1981) relate each z_t to its own future values or "forecast profile," where the profile in time t is interpreted as z_t's "permanent" component, $\bar{z}_t$. Thus, the estimated z_t forecast k periods ahead becomes the expected value of z_{t+k}, conditional on z_t's past values

$$\hat{z}_t(k) = E(z_{t+k} \mid \ldots, z_{t-1}, z_t) \tag{3}$$

which, because w accumulates past z's, may be written as

$$\hat{z}_t(k) = z_t + E(w_{t+1} + \ldots + w_{t+k} \mid \ldots, w_{t-1}, w_t) = z_t + \hat{w}_t(1) + \ldots + \hat{w}_t(k) \tag{4}$$

But from Eq. (2), each estimated w, say w_{t+i}, is

$$\hat{w}_t(i) = \mu + \lambda_i\varepsilon_t + \lambda_{i+1}\varepsilon_{t-1} + \lambda_{i+2}\varepsilon_{t-2}\ldots = \mu + \sum_{j=i}^{\infty}\lambda_j\varepsilon_{t+i-j} \tag{5}$$

Substituting Eq. (5) recursively into Eq. (4) and approximating to an infinite time horizon, we obtain

$$\hat{z}_t(k) \approx k\mu + z_t + \left(\sum_1^{\infty}\lambda_i\right)\varepsilon_t + \left(\sum_2^{\infty}\lambda_i\right)\varepsilon_{t-1} + \ldots$$

$$\hat{z}_t(k) - k\mu \approx z_t + \left(\sum_1^{\infty}\lambda_i\right)\varepsilon_t + \left(\sum_2^{\infty}\lambda_i\right)\varepsilon_{t-1} + \ldots \tag{6}$$

BN (1981) suggest that it is natural to interpret the LHS of Eq. (6) as z_t's "permanent" component, denoted as $\bar{z}_t$. The cyclical component, c_t, then is

$$\bar{z}_t - z_t = \left(\sum_1^{\infty}\lambda_i\right)\varepsilon_t + \left(\sum_2^{\infty}\lambda_i\right)\varepsilon_{t-1} + \ldots \tag{7}$$

The unknown μ and λ_i's in Eq. (5) must be estimated. Beveridge and Nelson suggest an ARIMA procedure of order $(p,1,q)$ with drift μ.

$$w_t = \mu + \frac{(1 - \theta_1 L^1 - \ldots - \theta_q L^q)}{(1 - \phi_1 L^1 - \ldots - \phi_p L^p)} \varepsilon_t = \mu + \frac{\theta(L)}{\phi(L)} \varepsilon_t. \tag{8}$$

Cuddington and Winters (1987, p. 127, Eq. (7)) realized that in the steady state, i.e, $L=1$, Eq. (8) reduces to

$$\bar{z}_t - \bar{z}_{t-1} = \mu + \frac{(1 - \theta_1 - \ldots - \theta_q)}{(1 - \phi_1 - \ldots - \phi_p)} \varepsilon_t = \mu + \frac{\theta(1)}{\phi(1)} \varepsilon_t \tag{9}$$

where μ will be the estimated mean, θ_i the estimated moving average terms, and ϕ_i the estimated autoregressive terms. Now iterate Eq. (9) recursively, i.e., replace t by $(t-1)$ and $(t-1)$ by $(t-2)$, etc. Then we get

$$\bar{z}_t - \bar{z}_{t-1} = \mu + \frac{\theta(1)}{\phi(1)} \varepsilon_t \tag{10}$$

$$\bar{z}_{t-1} - \bar{z}_{t-2} = \mu + \frac{\theta(1)}{\phi(1)} \varepsilon_{t-1}$$

$$\vdots$$

$$\bar{z}_1 - \bar{z}_0 = \mu + \frac{\theta(1)}{\phi(1)} \varepsilon_1$$

Adding these equations, the terms on the LHS cancel out except for $\bar{z}_t$ and $\bar{z}_0$, and on the RHS μ is added "t" times, and the fraction in the second term on the RHS is a constant to be multiplied by the sum of error terms. Thus, we obtain

$$\bar{z}_t = \bar{z}_0 + \mu t + \frac{\theta(1)}{\phi(1)} \sum_{i=1}^{t} \varepsilon_i \tag{11}$$

This is, except for notation, Newbold's (1990, p. 457, Eq. (6)) equation and the problem reduces to finding an initial value for $\bar{z}_0$.

Cárdenas (1991), in his unpublished dissertation, suggests that $\bar{z}_0 = z_0$, i.e., the very first data point of the original series. This makes intuitive sense. Because a forecast profile conditional on past values cannot be computed in the absence of past values, $\bar{z}_0 = z_0$ by definition. Formally, Cárdenas suggests the following (we changed the notation to conforms to ours here), where z_t refers to the original data series,

$$z_t - z_{t-1} = \mu + \sum_{i=1}^{p} \phi_i \Delta z_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t. \tag{12}$$

In words, the series of the first differences of z_t equals the series mean, adjusted for autoregressive and moving average terms. Bring the autoregressive term to the LHS to get

$$(z_t - z_{t-1}) - \left(\sum_{i=1}^{p} \phi_i \Delta z_{t-1}\right) = \mu + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \tag{13}$$

and expand both summation terms

$$(1 - \phi_1 L^1 - \phi_2 L^2 - \ldots - \phi_p L^p)(z_t - z_{t-1}) = \mu + (1 + \theta_1 L^1 + \ldots + \theta_q L^q)\varepsilon_t. \tag{14}$$

Rearrange Eq. (14) to obtain

$$z_t - z_{t-1} = \frac{\mu}{\phi(L)} + \frac{\theta(L)}{\phi(L)} \varepsilon_t \tag{15}$$

Now, recursively replace t with $(t-1)$, and $(t-1)$ with $(t-2)$, etc.

$$z_t - z_{t-1} = \frac{\mu}{\phi(L)} + \frac{\theta(L)}{\phi(L)} \varepsilon_t \tag{16}$$

$$z_{t-1} - z_{t-2} = \frac{\mu}{\phi(L)} + \frac{\theta(L)}{\phi(L)} \varepsilon_{t-1}$$

$$\vdots$$

$$z_1 - z_0 = \frac{\mu}{\phi(L)} + \frac{\theta(L)}{\phi(L)} \varepsilon_1$$

which, when added together "t" times, yield

$$z_t - z_0 = \frac{\mu}{\phi(L)} t + \frac{\theta(L)}{\phi(L)} \sum_{i=1}^{t} \varepsilon_i. \tag{17}$$

Rearranged, write

$$z_t = z_0 + \frac{\mu}{\phi(L)} t + \frac{\theta(L)}{\phi(L)} \sum_{i=1}^{t} \varepsilon_i. \tag{18}$$

In the steady state, i.e., $L=1$, Eq. (18) readily yields the permanent component of z_t,

$$\bar{z}_t = z_0 + \frac{\mu t}{\phi(1)} + \frac{\theta(1)}{\phi(1)} \sum_{i=1}^{t} \varepsilon_i \tag{19}$$

which, except for notation, is Cárdenas' (1991, p. 27, Eq. (15)) final formula. In practice, it is easy to set up a spreadsheet for Eq. (19) by replacing $\theta(1)$ and $\phi(1)$ with $(1-\Sigma\theta_i)$ and $(1-\Sigma\phi_i)$, i.e., with the estimated ARIMA coefficients. In our particular case, where the ARIMA did not result in any AR terms at all, the denominators fell out of Eq. (19) altogether, making the computation of the permanent, and hence cyclical, components, of the Colombian murder series even easier.

References

Bejarano, J.A., 1997. Inseguridad, violencia y actividad económica. Lecturas de Economía, Medellín, Colombia, pp. 7–24.

Beveridge, S., Nelson, C.R., 1981. A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the 'business cycle'. Journal of Monetary Economics 7, 151–174.

Brito, D.L., Intriligator, M.D., 1992. Nacro-traffic and guerrilla warfare: a new symbiosis. Defence Economics 3, 263–274.

Bushnell, D., 1993. The Making of Modern Colombia: A Nation In Spite of Itself. University of California Press, Berkeley, CA.

Cárdenas, M., 1991. Coffee Exports, Endogenous State Policy and the Business Cycle. PhD thesis. Economics. University of California, Berkeley, CA.

Collier, P., 1999. On the economic consequences of civil war. Oxford Economic Papers 51, 168–183.

Collier, P., 2000. Doing well out of war: an economic perspective. In: Berdal, M., Malone, D.M. (Eds.), Greed and Grievance: Economic Agendas in Civil War. Lynne Rienner, Boulder, CO, pp. 91–111.

Cuddington, J., Winters, L.A., 1987. The Beveridge–Nelson decomposition of economic time series. Journal of Monetary Economics 19, 125–127.

Dinar, A., Keck, A., 1997. Private irrigation investment in Colombia: effects of violence, macroeconomic policy, and environmental conditions. Agricultural Economics 16, 1–15.

Giraldo, J., 1996. Colombia: The Genocidal Democracy. Common Courage Press, Monroe, ME.

Guerrero, R., 1998. Epidemiology of violence in the Americas: the case of Colombia. In: Burki, S.J., Aiyer, S.R., Hommes, R. (Eds.), Annual World Bank Conference on Development in Latin America and the Caribbean: Poverty and Inequality (Bogotá, Colombia). The World Bank, Washington, DC, pp. 95–100.

Harvey, A.C., Jaeger, A., 1993. Detrending, stylized facts and the business cycle. Journal of Applied Econometrics 8, 231–247.

Hodrick, R.J., Prescott, E.C., 1997. Postwar US business cycles: an empirical investigation. Journal of Money, Banking, and Credit 29, 1–16.

Kirk, R., 2003. More Terrible than Death: Massacres, Drugs, and America's War in Colombia. Public Affairs, New York.

Londoño, J.L., 1998. Violence, psyche, and social capital. In: Burki, S.J., Aiyer, S.R., Hommes, R. (Eds.), Annual World Bank Conference on Development in Latin America and the Caribbean: Poverty and Inequality (Bogotá, Colombia). World Bank, Washington, DC, pp. 71–82.

Maravall, A., del Río, A., 2001. Time aggregation and the Hodrick–Prescott filter. Working Paper No. 108. Bank of Spain, Madrid.

Miller, S.M., 1988. The Beveridge–Nelson decomposition of economic time series: another economic computation method. Journal of Monetary Economics 21, 141–142.

Newbold, P., 1990. Precise and efficient computation of the Beveridge–Nelson decomposition of economic time series. Journal of Monetary Economics 26, 453–457.

Ravn, M.O., Uhlig, H., 2002. On adjusting the Hodrick–Prescott filter for the frequency of observations. Review of Economics and Statistics 84, 371–380.

Richani, N., 1997. The political economy of violence: the war-system in Colombia. Journal of Interamerican Studies and World Affairs 39, 37–81.