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Unemployment, poverty and police performance: an ARDL analysis of crime in São Paulo

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Determinants of crime in São Paulo: shedding some light on this puzzle

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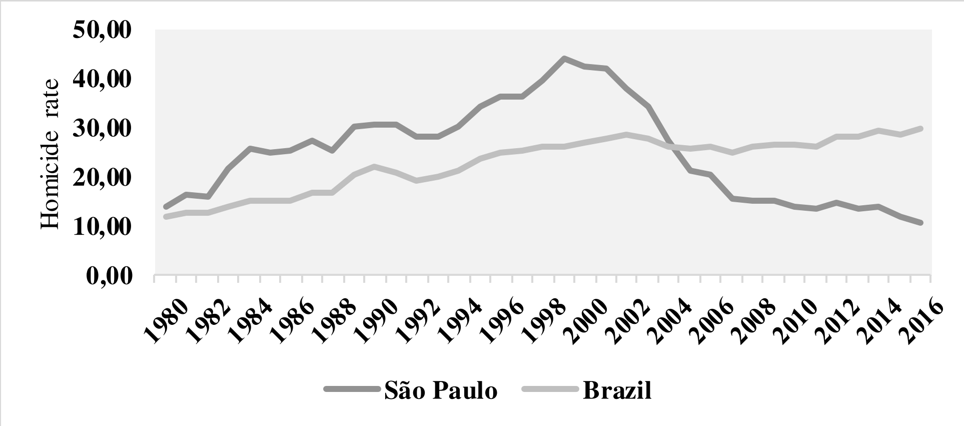
1. Introduction

Brazil is one of the deadliest countries in the world, according to the Datasus[1] 65,602 homicides were registered in 2017. Criminality has been rising since the 1990s in almost all Brazilian states. However, the State of São Paulo is in the opposite direction of this trajectory.

Figure 1: Annual Evolution of Homicide Rate in Brazil and São Paulo (1980-2016)



Source: DataSus/Ministry of Health.

Figure 1 shows the annual evolution of the number of homicides per 100,000 inhabitants. While the homicide rate in Brazil constantly rises, from 2000 the homicide rate in the State of São Paulo has been continuously declining. This leads us to a question: what are the causes of this decline in crime in São Paulo. In the past decade, many researchers tried to explain this phenomenon. However, this is not an easy task, and many are the factors pointed out as a reason for this decline.

Goertzel and Khan (2007) attributed this reduction in crime to the introduction of "zero tolerance" policies by the State of São Paulo during the last twenty years. Willis (2009) presents a more controversial explanation; the author suggests that the rise, in the 1990s, of PCC (*Primeiro Comando da Capital*), a criminal organization, led to a significant reduction of crime. Cabral (2016) claims that the Criminal Information System – INFOCRIM – implemented in the 2000s is one of the many factors that contributed to the decline in crime in São Paulo State. Employing a spatial difference-in-difference model, she found results that the INFOCRIM was responsible to a reduction of 6.183 in homicide rates during the period of 2000-2010. The PCC hypothesis was tested by Justus *et al.* (2018) using a first difference approach with a spatial structure based on a series of attacks made by PCC in 2006 as a proxy for the power of the organization. The results showed no statistical evidence that PCC contributed to the decline in homicides. It is important to emphasize that the results made are only valid if the attacks were exogenous.

The hypothesis defended by us to explain the reduction of São Paulo's crime consists not only by a more effective police, but also better economic conditions – during the 2000s Brazil was in an economic growth period, with an increase of individual income and a decline in unemployment. There are few studies employing a time-series econometric approach to analyze crime data in Brazil (Justus and Kassouf, 2012; Justus and Kassouf, 2013). In this paper, we are going to focus in a single unit space – São Paulo city – to avoid the bias of spatial dependence already identified in many studies in crime (Almeida *et al*, 2005; Cabral, 2016;

[1] Institution of the Brazilian Ministry of Health responsible to compile the data of homicides for Brazil.

Vital, 2018). It is common in the crime literature the presence of endogeneity of some variables due to reverse causality, in a time-series analysis this is not a major concern.

Aiming to validate our hypothesis that the decline in the São Paulo's crime rate are linked to both economic and social conditions, and an improvement of police performance, we employed an autoregressive distributed lag (ARDL) bounds testing approach to examine the intertemporal causal relationship between homicide rate and unemployment rate, maximum wage of the 10% most impoverished part of the population_and percentage of arrests due to drug traffic[2]. Along with this introductory section, this paper is divided as follows: section 2 presents the model and methodology used; section 3 addresses the results; section 4 concludes the paper with some implications of the found results.

2. Methodological Approaches

To explain crime reduction, we need to look at two models, where one starts from a microeconomic model to reach the macroeconomic model. First, we need to investigate at the microeconomic level whether or not to commit a crime. To this end, we propose a different approach, in which each person has a tendency within them to do some harm. And then we look at the macroeconomic level for a long-term relationship between a set of crime-related variables.

2.1. Empirical Strategies in Microeconomics

The causal relationship between crime and socioeconomic conditions is a question that intrigues economists since a long time ago (Masih and Masih, 1996; Narayan and Smith, 2004; Lee and Holoviak, 2006; Detotto and Manuela, 2010; Hamid *et al,* 2013). Masih and Masih (1996), investigating crime in Australia, points out that dwelling commencements (a proxy for wealth) have a greater impact in crime than unemployment and police. Lee and Holoviak (2006) on the other hand found strong evidence of a long-run equilibrium relationship between crime and youth-male unemployment for the Asia-Pacific countries.

In his seminal paper, Becker (1968) proposed a model based on the rationality of the potential criminal. The decision to commit or not a crime is a maximization of the utility of the individual based on the potential monetary profit of the illegal activity. Levitt (1997) employed an instrumental variable approach using electoral cycles to determine the impact of police on crime in the USA. The author found evidence of a negative relation between homicides and police. Shoesmith (2010) analyses US crime through a VECM approach and the results showed a close link between the crime rates and the percentage of prison resources devoted to drug offenders. The decision of an individual to commit a crime can be influenced by many variables.

We propose a different approach, every person has inside them a tendency to do some evil. Some more than the others, such as psychopaths. In the 1970s the famous prison experiment conducted by Phillip Zimbardo at Stanford University tried to shed some light at this question. Zimbardo (2008) named this behavior "Lucifer effect", to depict the ease with good people can fall from grace, as did Lucifer, God's favorite angel. The environment also plays a major role in behavior and attitudes. The young population that lives in neighbors where they do not see a bright future for themselves are much more susceptible to be influenced by criminals to ingress in illegal activities. This phenomenon is called contagious effect, as the

[2] This variable is used as a proxy for police activity.

individuals are susceptible to be "contaminated" by the crime. We can summarize our model by the following equation:

$$Y_i(t) = \lambda_0(t) + f(X_{s,t}) \quad (1)$$

In which $Y_i(t)$ is the decision of individual i in time t to commit or not a crime. The Lucifer effect is $\lambda_0(t)$, and the contagious effect is $f(X_{s,t})$, it is a function of variables that can influence the potential criminal's decision. It is important to emphasize that the the individual's decision varies in time, while the variables $X_{s,t}$ varies in space, s, and time, t.

2.2. Macroeconomic model

Autoregressive models of distributed lag (ARDL) constitute an old approach of dynamic specification regression models, that is, with different lagged terms for the dependent and independent variables. Following the cointegration revolution, consolidated in the late 1980s with the work of Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990) and Johansen (1991), the ARDL models fell into disuse, but were revived in the late 1990s from the works of Pesaran and Pesaran (1997), Pesaran and Shin (1999) and Pesaran et al (2001). These authors have proposed a way to use ARDL models that allows us to capture the cointegration relations between the variables present in the model. This method has some econometric advantages when compared to conventional cointegration methods. First, it can be applied even in the case where variables are of mixed order of integrating, i.e. I (0) and I (1) (Pesaran and Pesaran, 1997).

Second, the problems of endogeneity are avoided and generally the model provides unbiased long-run estimates and valid t-statistics (Narayan, 2005). Third, the small sample properties of the ARDL approach is better than multivariate cointegration and it's very appropriate in the analysis of models based on small sample datasets (Amusa *et al.,* 2009). The Pesaran test checks the existence of a long-run relationship between a set of variables. The first step was to estimate by ordinary least squares (OLS) the unrestricted error-correction model:

$$\Delta crime_t = a_0 + \sum_{i=1}^{p} a_{1i} \Delta crime_{t-i} + \sum_{i=0}^{p} a_{2i} \Delta drugarrests_{t-i} + \sum_{i=0}^{p} a_{3i} \Delta unemployment_{t-i} + \sum_{i=0}^{p} a_{4i} \Delta poorwages_{t-i} + b_1 crime_{t-1} + b_2 drugarrests_{t-1} + b_3 unemployment_{t-1} + b_4 poorwages_{t-1} + \varepsilon_t \quad (2)$$

The second step was to use Wald test to check if the long-run multipliers (b_s) are all zero. The Wald test produces F-statistics with a non-standard distribution. Pesaran *et al.* (2001) propose two sets of critical values for a given significance level, the upper and lower critical bounds. In case the F-statistics is smaller than the lower critical value, there is no cointegration; if the F-statistics is between the critical values, the test is inconclusive; if it is above the upper bound it means that the series are cointegrated. However, we adopted the critical values of Narayan (2005) for the bounds F-test rather than Pesaran *et al.* (2001) given that the critical values produced by Narayan (2005) in small samples are more appropriate than Pesaran's. In case of an inconclusive Pesaran's test we check for cointegration using the Banerjee *et al.* (1998) approach, which considers the t-statistics of the error correction mechanism (ECM) estimate. This statistic is compared with the critical value established in Banerjee *et al.* (1998, p. 276) considering the sample size ($n = 42$) and the number of regressors.

Once the series cointegration was established, the next step is to select the best ARDL model specification. The formal representation of the model is commonly denoted by ARDL (p, q_1, ..., q_k), where p is the number of lags of the dependent variable and q_k is the number of lags of the kth explanatory variable. The ARDL (p, q_1, ..., q_k) model applied to (2) equation can be written as follows:

$$crime_t = c_0 + \sum_{i=1}^{p} c_{1i} crime_{t-i} + \sum_{i=0}^{q_1} c_{2i} drugarrests_{t-i} + \sum_{i=0}^{q_2} c_{3i} unemployment_{t-i} + \sum_{i=0}^{q_3} c_{4i} poorwages_{t-i} + u_t \quad (3)$$

If a cointegration relationship between the variables is found, the long-run multipliers are linear functions of equation (3) coefficients. Therefore, we make all the variables in equation (3) equal to their respective contemporaneous versions to obtain the cointegration equation:

$$crime_t = d_0 + d_2 drugarrests_t + d_3 unemployment_t + d_4 poorwages_t + v_t \quad (4)$$

In which $d_0 = \frac{c_0}{1-\sum_{i=1}^{p} c_{1i}}$, $d_m = \frac{\sum_{i=0}^{qm} c_{mi}}{1-\sum_{i=1}^{p} c_{1i}}$ for $m = 2,3,4$ and $v_t = \frac{u_t}{1-\sum_{i=1}^{p} c_{1i}}$. In the last step, we estimate by OLS the short run coefficients:

$$\Delta crime_t = h_0 + \sum_{i=1}^{p} h_{1i} \Delta crime_{t-i} + \sum_{i=0}^{q_1} h_{2i} \Delta drugarrests_{t-i} + \sum_{i=0}^{q_2} h_{3i} \Delta unemployment_{t-i} + \sum_{i=0}^{q_3} h_{4i} \Delta poorwages_{t-i} + h_5 \hat{v}_{t-1} + w_t \quad (5)$$

Where $h_5 \hat{v}_{t-1}$ is the error-correction mechanism. The Schwarz–Bayesian information criteria were used to find the ideal number of lags. To ensure the stability of long-run parameters, we employed the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares (CUSUMQ), both proposed by Brown et al. (1975). In order to determine if there is a causal relationship between the variables, we adopted the Granger causality test that Granger (1969) augmented by the error-correction term. This test has been widely applied to examine the direction of causality among economic time series. Therefore, the Granger causality test involves specifying a multivariate pth order vector error correction model given by equation (6).

$$\begin{bmatrix} \Delta crime_t \\ \Delta drugarrests_t \\ \Delta unemployment_t \\ \Delta poorwages_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \beta_{11i} & \beta_{12i} & \beta_{13i} & \beta_{14i} \\ \beta_{21i} & \beta_{22i} & \beta_{23i} & \beta_{24i} \\ \beta_{31i} & \beta_{32i} & \beta_{33i} & \beta_{34i} \\ \beta_{41i} & \beta_{42i} & \beta_{43i} & \beta_{44i} \end{bmatrix} \begin{bmatrix} \Delta crime_{t-i} \\ \Delta drugarrests_{t-i} \\ \Delta unemployment_{t-i} \\ \Delta poorwages_{t-i} \end{bmatrix} + \begin{bmatrix} \lambda_1 \hat{v}_{1,t-1} \\ \lambda_2 \hat{v}_{2,t-1} \\ \lambda_3 \hat{v}_{3,t-1} \\ \lambda_4 \hat{v}_{4,t-1} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \\ u_{3,t} \\ u_{4,t} \end{bmatrix} \quad (6)$$

3. Data and Results

The data used in this paper are quarterly times series spanning the period 01q2005 to 02q2015. Table 1 highlights some descriptive statistics and description of variables. In Figure 2, a representation of the graphics behavior at the level form of crime, drug arrests, unemployment and poor wages respectively.

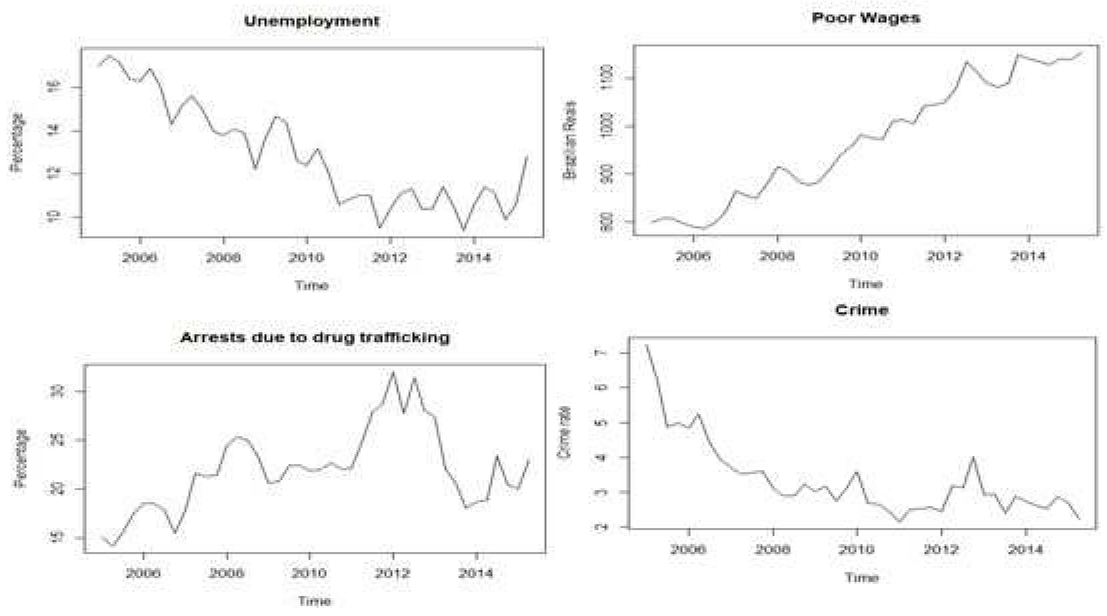
Table 1. Summary statistics, São Paulo, first quarter 2005 – second quarter 2015

Series	Definition	Source	Mean	Std. Dev.	Max.	Min.
Crime	Robbery and homicide rate per 100,000 inhabitants	SSP/SP[3] and IBGE	3.358	1.089	7.235	2.154
Drug arrests	Percentage of arrests due to drug trafficking	SSP/SP	21.98	4.211	32.00	14.22
Unemployment	Total unemployment rate (%)	SEADE[4]	12.92	2.39	17.50	9.40
Poor wages	Maximum wage of the 10% poorest of the population (in Brazillian Reals)	DIEESE[5]	971.4	124.98	1154.0	787.0

Source: Calculated by the Authors

ARDL bounds testing allows variables either I(0) or I(1) to be cointegrated, but does not allow cointegration for those that are I(2). The methodological framework employed to investigate the relationship amongst these variables consists of three steps. The first step is to test the order of integration. Table 2 gives the results of the augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test statistics. These tests are used to detect the presence of a unit root for the individual time series and their first differences. Table 2 presents all unit root tests results for each variable involved. The null hypothesis of ADF and PP unit root tests is that the variable is not stationary. In contrast, the null hypothesis of the KPSS test is that the variable is stationary.

Figure 2: Series Crime, Drug arrests, Poor wages and Unemployment, 01q2005 to 02q2015



Source: Prepared by the authors

[3] Department of Public Safety of São Paulo.

[4] SEADE Foundation is linked to São Paulo's government and is responsible for the production and dissemination of socioeconomic and demographic analysis and statistics of the State.

[5] The Intersindical Department of Statistics and Socioeconomic Studies (DIEESE) is an entity created and maintained by the Brazilian trade union movement.

At 5% significance level, all tests conclude that crime, drug arrests and poor wages variables are I (1) and unemployment is I (0). This result allows the possibility of cointegration in ARDL models. The ARDL cointegration test, assumed that only one long-run relationship exists between the dependent variable and the exogenous variables (Pesaran, Shin and Smith, 2001, assumption 3). The next step is estimating equation (2) by OLS.

Table 2: Unit roots test (sample: 01q2005 to 02q2015)

Series	Test value			Conclusion
	ADF	PP	KPSS	
Crime	-2,90	-2,81	0,18**	I(1)
d(Crime)	-7,30***	-7,62***	0,34	
Drug arrests	-0,75	-0,99	0,16**	I(1)
d(Drug arrests)	-3,02**	-4,88***	0,19	
Unemployment	-4,87***	-3,68**	0,07	I(0)
d(Unemployment)	-	-	-	
Poor wages	-2,73	-2,67	0,16**	I(1)
d(Poor wages)	-7,55***	-8,95***	0,26	

Source: Calculated by the Authors

Notes: (1) **, *** denote statistical significance at the 5% and 1 % levels of significance, respectively.

In the bounds testing approach, the value of the F-statistic is sensitive to the number of lags imposed on the variables (Bahmani- Oskooee and Goswami, 2003). Thus, the optimal order of lags was selected based on Schwarz–Bayesian information criteria as suggested by Pesaran *et al.* (2001), which pointed out one lag optimum. The bounds testing result in Table 3 confirms the existence of an equilibrium relationship at a 0.10 level of significance when crime is the dependent variable. Banerjee *et al.* (1998) approach considering three regressors and 50 observations concludes that there is a cointegration relation at a 0.05 level of significance.

Table 3 – Bounds testing for cointegration

F-statistics	95% Critical value bonds		90% Critical value bonds	
	I(0)	I(1)	I(0)	I(1)
F(crime) = 3.88	3.10	4.09	2.59	3.45
F(drug arrests) = 2.40				
F(unemployment) = 1.83				
F(poor wages) = 2.48				
t-statistics	**95% Critical value**		**90% Critical value**	
t(crime) = -4.11**	3.82		3.45	
t(drug arrests) = -3.23				
t(unemployment) = -2.83				
t(poor wages) = -3.29				

Source: Calculated by the Authors

Given that the series cointegration were stablished, we estimated equation 2.3 using Schwarz criteria to find the ideal number of lags. The best specification was an ARDL (1, 1, 0, 0). The results from the relationship of Equation (4) along with a number of diagnostic tests for the ARDL (1, 1, 0, and 0) are shown in Table 4. The estimated elasticity regarding unemployment is statistically significant at a 0.05 level and is positive, which indicates a positive long-run relation between crime and unemployment in São Paulo.

The idea that unemployment induces crime is grounded by Becker's model, in which a decrease in income associated with involuntary unemployment increases the relative returns of illegal activities. The magnitude of this effect can be considered very large, and an increase of 1% in the unemployment is linked to a 0.765% increase in the crime rate. The long-run coefficients of the percentage of arrests due to drug trafficking and the maximum wage of the 10% most impoverished part of the population are positive and negative, respectively. However, at a 0.1 significance level neither of them is significant. Implying that in a long spam, those variables are not statistically significant linked to crime.

The short-run dynamics described in Equation (5) and some diagnostic tests are presented in Table 5. The short-run coefficients of poor wages, unemployment and drug arrests, as well as the seasonal dummies, are not significant at conventional levels. The adjustment coefficient is significant at 0.01 level, which means that the cointegration relation between the variables impact crime. The value of 0.34 points that 34% of the difference between the effective value and the long-run value is corrected each year. Implying that it takes approximately three years for a shock in the crime rate to dissipate.

Table 4: ARDL results

Panel A: Long-run coefficients for the ARDL (1,1,0,0) model			
Variable	**Drug arrests**	**Unemployment**	**Poor wages**
Coefficient	0.381	0.765	-0.307
t-statistic	0.941	3.542	-1.633
p-value	0.353	0.001	0.112

Panel B: Diagnostic tests of the underlying ARDL model		
Residual tests	**Statistic's value**	**p-value**
Serial correlation	0.015	0.90
Normality	0.452	0.79
Heteroscedasticity	0.348	0.56

Source: Calculated by the Authors

After estimating the model, it is usual in the literature of ARDL models to perform the cumulative sum of recursive residuals (CUSUM) and the CUSUM of squares (CUSUMSQ) tests in order to ensure the stability of the long-run parameters. Figures 3a and 3b present the CUSUM and CUSUMSQ respectively. In both figures, the dotted red lines represent the critical lower and upper bounds at a 0.05 level of significance. As the plot of the CUSUM and CUSUMSQ is confined within the 5% critical bounds, we conclude that the long-run coefficients of the ARDL (1,1,0,0) are stable.

Table 5. Error Correction Representations of ARDL Model, ARDL (1, 1, 0, 0)

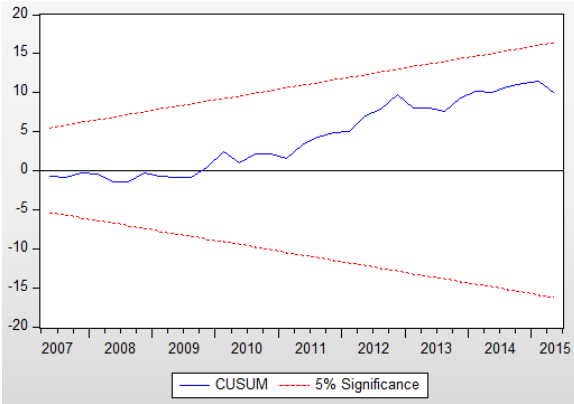
Panel A: Error-correction estimation results. The dependent variable is Δcrime					
Variable	**Δ drug arrests**	**Seas_1**	**Seas_2**	**Seas_3**	**ECt-1**
Coefficient	-0.2065	0.0072	-0.0002	-0.0430	-0.3466
t-statistic	-1.1461	0.3917	-0.0012	-2.188	-4.1128
p-value	0.2600	0.6978	0.9990	0.0358	0.0002

Panel B: Diagnostic tests			
R^2	0.4337	Se	0.1056
R^2 ajusted	0.3708	Rss	0.4013
Dw-statistic	1.9616		

Source: Calculated by the Authors

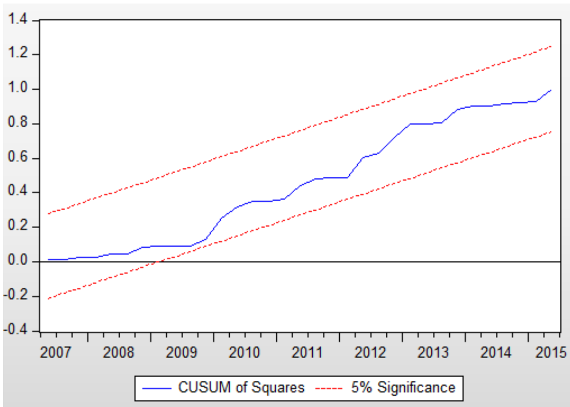
Having a cointegrating relationship among the variables (*crime_t*, *drug arrests_t*, *unemployment_t*, *poor wages_t*) on the basis of the results of the bounds test, the Granger causality test was conducted, Table 6. The results of the Granger causality tests show a bidirectional relation between crime and the proxy of the effectiveness of police in the model (*drug arrests_t*). The endogeneity of police and crime were already identified in many others papers (Levitt, 1997; Donohue and Levitt, 2001; Di Tella, 2004) and led to a broad discussion about the simultaneity of police and crime. Given robustness to our previous results, unemployment is causing crime at conventional levels of significance, at the same time that crime is not causing unemployment. The salaries of the most impoverished part of the populations does not have a statistically significant causal relation with crime.

Figure 3a– Cumulative Sum of Recursive Residuals Test (CUSUM)



Source: Calculated by the Authors

Figure 3b – Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)



Source: Calculated by the Authors

Table 6 – Granger causality test

Null Hypothesis	F-statistic	Prob.
$drug\ arrests_t$ **does not cause** $crime_t$	4.058	0.026
$crime_t$ **does not cause** $drug\ arrests_t$	3.149	0.055
$unemployment_t$ **does not cause** $crime_t$	0.957	0.393
$crime_t$ **does not cause** $unemployment_t$	3.724	0.034
$poor\ wages_t$ **does not cause** $crime_t$	1.369	0.267
$crime_t$ **does not cause** $poor\ wages_t$	0.879	0.424

Source: Calculated by the Author.

Conclusion and political implications

Several studies are conducted to evaluate public policies related to the fight against crime, considering their impact on the economic and social well-being of the entire population. In the case of Brazil, the city of São Paulo has experienced a decline in it's homicide rates for the last two decades, unlike Brazil's, which increased by 0,25% per year. This study has examined the determinants of the robbery and homicide rate per 100,000 in the city of São Paulo during the period of 2005-2015. Regarding this, the method chosen for the analysis was the ARDL bounds testing approach, and the determinants investigated were percentage of arrests due to drug trafficking, total unemployment rate and maximum wage of the 10% most impoverished part of the population.

The results presented that there were no statistically significant short-run effects in the model, but there is statistical evidence of cointegration. The long-run relationship indicates that a 1% increase in total unemployment rates increase approximately 0,76% in robbery and homicide rate per 100,000. No other variable had statistical significance. The stability of the long-run parameters was checked via CUSUM and CUSUMQ. The Granger causality tests showed a bidirectional relation between crime and the proxy of the effectiveness of police and unemployment is causing crime.

Investments in increasing police force are often considered as a good public policy initiative to reduce crime. The results of our ARDL model of the crime in São Paulo city showed otherwise. A decline in the rate crime is much more related to a decline in the unemployment than to an increase in police performance. This result reinforces the previous evidence in Justus and Kassouf (2012) and Justus and Kassouf, (2013).

In the conception of new public policies to fight São Paulo's crime, the policy makers should take into account that economic activity is intimately related to criminal activities in the long run. Public policies that encourage the labor market and reduce the unemployment rate are more effective in the long-run term in the combat of crime.

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