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Crime and Police Personnel in Malaysia: An Empirical Investigation

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Abstract: The economic theory on crime behavior proposed by Becker (1968) suggests that an increase in the number of policemen can deter crimes. However, recent studies found a positive relationship between police personnel and crime rates. The purpose of the present study is to investigate the effect of police personnel on 15 categories of crime rates in Malaysia for the period of 1973 to 2005 by using the vector error-correction model. Our results suggest that 8 categories of crime rates support Becker's crime economic theory, while 6 categories of crime support the 'long-run natural rate of crime' hypothesis.

Key words: Crime rates, police personnel, cointegration
JEL classification: E02, J21, K42

1. INTRODUCTION

To sustain living standards over the long run, it is important to maintain the long-term growth of a country's output. Increase in output raises the standard of living, and studies have shown that the growth rates of physical and human capital stocks as well as the rate of technological change are key determinants of long-term economic growth. Accumulated savings channeled to investment in plant, equipment, technology and human capital will

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enhance growth. Increase in output per person raises income and ultimately leads to the accumulation of wealth. The role of the government in this process is to foster a stable political climate and to define, protect and enforce 'property rights'.

Property rights is defined as the ownership of goods and services as well as resources and set limits on the transfer and use of those goods and services (Marby & Ulbrich, 1989). Without enforcing property rights, one cannot establish who owns them and what rights the owners have. If property can be freely seized through theft and deception, no one will have the incentive to invest and accumulate wealth. Thus, the protection of property from being taken away forcefully or illegally is the most basic of all property rights (Witte & Witt, 2001). Furthermore, without government intervention, the market cannot work effectively and the strongest will acquire the most goods and services rather than those who legitimately acquire the goods through transactions.

Crime has always been part of our everyday life. Crime results in misery and loss of life. In Malaysia, we identify 15 categories of crimes, namely: murder, attempted murder, gang robbery with firearms, gang robbery without firearms, armed robbery, robbery without arms, rape, assault, day house burglary, night house burglary, lorry-van theft, car theft, motorcycle theft, bicycle theft and other theft. In Malaysia as well as anywhere else, criminal activities are clearly an act of brute force, engaging in the seizing of property and person's life and thus, violating property rights. The role of the government in crime prevention is protecting persons and property as well as providing a criminal justice system. One common method used by the government to deter crime is to increase the budget for police expenditure. With a higher budget, the police department will be able to hire additional police personnel, recruit more qualified staff, improve their training and supply them with better equipment – more firepower and sophisticated communication devices – to combat crime. Thus, it is expected that higher police expenditure will result in a more efficient and effective police force, thereby increasing the probability of arrest and decreasing a criminal's incentive to commit crime.

However, despite the economic model put forward by Becker (1968) and Ehrlich (1973) that crime does not pay – the war against crime is to increase police strength and thereby reduce crime (Lin, 2009; Hakim, Ovadia, Sagi & Weinblatt, 1979; Vollaard & Koning, 2009), – numerous studies have suggested otherwise, that is, an increase in the number of police personnel increases crime rates (Fajnzylber, Lederman & Loayza, 2002; Jacob & Rich, 1981; Buck, Gross, Hakim & Weinblatt, 1983). Yet, other studies show that the relationship between crime rates and police personnel is not significant (Bennett & Bennett, 1983; Meera & Jayakumar, 1995; Allison, 1972). These mixed findings or 'puzzle' has created controversy among economists and criminologists. Some of the reasons put forward to explain the puzzle are endogeneity problem with respect to the relationship between police and crime rates (Decker & Kohfeld, 1985; Lin, 2009); different measures for police strength (Ogilvie, Allard & Stewart, 2008); error in the measurement of crime (Chilton, 1982); too few or incorrect set of social system/economic control variables were included in the equation (Bennett & Bennett, 1983); aggregation and unobserved heterogeneity bias (Cherry, 1999; Cherry & List, 2002).

The purpose of the present study is to investigate the impact of police personnel on crime rates in Malaysia using disaggregated crime data as suggested by Cherry (1999) and Cherry & List (2002). Total number of crimes are divided into violent and property crimes.

Violent crime is further divided into murder, attempted murder, armed robbery, robbery, rape and assault, while property crime is divided into daylight burglary, night burglary, lorry-van theft, car theft, motorcycle theft, bicycle theft and other theft. To eliminate simultaneity bias, we estimated our crime model using the vector error-correction model proposed by Johansen (1988) and Johansen & Juselius (1990). In this study, we used the number of police personnel as deterrence to crime. Despite the reservations of Marvell & Moody (1996), Jacob & Rich (1981), Bittner (1974) and Skogan (1980) who contended that not all police personnel are involved in combating crime and only a small fraction are assigned to the homicide department, and the fact that it has been used in other studies, we believe that it is an empirical question to determine the appropriateness of using the number of police as a proxy for police strength. Due to constraints of data availability, our period of study is limited to the period 1973 to 2005.

The paper is organized as follows. In the next section, we review briefly the empirical work related to crime and police personnel, and the method used in the study. In section 3, we discuss the empirical results. The last section presents our conclusion.

2. LITERATURE REVIEW

2.1 Related Literature

The Becker-crime-police (BCP) puzzle emerged in recent years concerning the effect of the police on crime. Numerous empirical evidence show a positive impact of increasing police strength on crime rates. On the other hand, some studies did not find any significant impact of the police force on crime rates. This is in contrast to the model predicted by Becker (1968) that one way of reducing crime is by increasing the number of police personnel in the area. Cherry & List (2002) and Cherry (1999) advocated that the positive relationship between the police and crime rate is due to aggregation bias. Aggregation and heterogeneity in the unit of observation may lead to spurious relationships that incorrectly imply or exaggerate deterrent effects. In their study, they found out that deterrent effects have heterogeneous impacts across crime types.

Allison (1972) proposed the unbalanced growth model of Baumol (1967) in which she claimed that the cost of externalities rises more rapidly than the population size. In other words, as the population rises, the crime rate (an externality) also increases at a faster rate. Thus, crime reduction can only be achieved with a faster increase in police expenditure. On the other hand, Furlong & Mehay (1981) argued that criminals are more concerned with police performance (arrest, clearance and conviction rates) rather than police inputs (police expenditure, number of policemen, armed and unarmed personnel). Thus, a higher level of inputs does not necessarily deter criminals.

Buck *et al.* (1983) and Friedman, Hakim & Spiegel (1989) proposed the "long-run natural rate of crime" to explain the positive effect of police on crime rates. According to Friedman *et al.* (1989), the police can deter crime in the short run but not in the long run. In the long run, criminals may learn how to cope with police practices and by committing more crimes, they may improve their techniques in such a way that previously increased policing become no longer effective. Buck *et al.* (1983), on the other hand, contended that certain crimes (burglaries, robberies, vehicle thefts and larcenies) are considered the natural level of crime. This type of crimes give high net returns and is unaffected in the long run by conventional police outlays. The net expected returns on these crimes are very high and provide a substantial incentive to people who are willing to be involved in illegal activity. Any effort to mobilize police forces to curtail this type of crime is futile.

2.2 Testing for Long-Run Relationship between Crime and Police

In this study, we specified the crime-police equation for Malaysia as follows:

$$crime_{it} = \alpha_0 = \alpha_1 police_t + \mu_t \quad (1)$$

where small letters indicate variables in natural logarithm and μ_t is the error term. The parameters α are to be estimated and *i* indicates different types of crime rates. It is *a priori* that we expect $\alpha_1 < 0$ or $\alpha_1 > 0$. Police strength has a negative effect on crime rate as per the economic model proposed by Becker (1968). In other words, the presence of more police personnel in an area can deter the occurrence of crime in that area. On the other hand, the positive impact of police on crime rates would suggest that crime does pay as the net expected return is too high for a criminal to leave the illegal activity.

Estimating equation (1) using ordinary least squares (OLS) is not straightforward because the estimated equation is subject to the so-called spurious regression results (Granger & Newbold, 1974). According to Granger and Newbold (1974), a spurious regression is the result of estimating an equation containing non-stationary economic variables. Nevertheless, recent advances in time-series analysis have yielded new procedures for estimating long-run and short-run econometric relationships between non-stationary variables. One such procedure which has become widespread in the economic literature is the use of dynamic specification with an error-correction mechanism (ECM) in single-equation and multi-equation macroeconomic forecasting models. However, ECM model is not of recent origin as it was introduced by Phillips (1954) and first used in economics by Sargan (1964). The ECM models only started gaining recognition amongst economists and econometricians since the published work of Davidson, Hendry, Sbra & Yeo (1978). In Davidson *et al.*'s study (1978), the ECM models which include the dynamics of both the short-run (changes) and long-run (levels) adjustment processes were used to specify the United Kingdom's consumption function. The favorable performance of the ECM model relative to the traditional model has inspired other researchers to use the ECM approach in economic modeling. Although the work of Hendry and associates (1979, 1983) on aggregate consumption and money demand has been very influential, it was Granger (1981, 1986) who linked the time-series properties of economic time-series, in particular, to the concept of cointegration and the ECM modeling approach.

In this study, to test for cointegration and the ECM modeling, we employed Johansen's (1988) and Johansen & Juselius' (1990) multivariate maximum likelihood estimation procedure. Detailed exposition of the Johansen-Juselius technique is provided in the works of Dickey, Jansen & Thornton (1991), Cuthbertson, Hall & Taylor (1992) and Charemza & Deadman (1992). However, a brief discussion on the Johansen-Juselius technique is provided below. We begin by defining a k-lag vector autoregressive (VAR) representation:

$$X_t = \alpha + \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + \nu_t \, (t = 1, 2, \ldots, T) \quad (2)$$

where X_t is a $px1$ vector of non-stationary $I(1)$ variables, α is a $px1$ vector of constant terms, $\Pi_1, \Pi_2 ... \Pi_k$ are pxq coefficient matrices and ν_t is a $px1$ vector of white Gaussian noises with mean zero and finite variance. Equation (2) can be reparameterised as follows:

$$\Delta X_t = \alpha + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi_k X_{t-k} + \nu_t \tag{3}$$

where $\Gamma_i = -I + \Pi_1 + \Pi_2 + ... + \Pi_i$ $(i = 1, 2, ... k-1)$ and Π is defined as

$$\Pi = -I + \Pi_1 + \Pi_2 + ... + \Pi_k. \tag{4}$$

Johansen (1988) shows that the coefficient matrix Π_k contains the essential information about the cointegrating or equilibrium relationships between the variables in the data set. Specifically, the rank of the matrix Π_k indicates the number of cointegrating relationships existing between the variables in X_t. In this study, for a two case variable, X_t = (crime and unemployment) and so $p = 2$. Therefore, the hypothesis of cointegration between crime and unemployment is equivalent to the hypothesis that the rank of $\Pi_k = 1$. In other words, the rank r must be at most equal to $p - 1$, so that $r \leqslant p-1$, and there are $p - r$ common stochastic trends. If the $r = 0$, then there are no cointegrating vectors and there are p stochastic trends. The Johansen-Juselius procedure begins with the following least square estimating regressions:

$$\Delta X_t = \alpha_1 + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \omega_{1t} \tag{5}$$

$$X_{t-p} = \alpha_2 + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \omega_{2t} \tag{6}$$

Defining the product moment matrices of the residuals as $S_{ij} = T^{-1} \sum_{t=1}^{T} \omega_{it} \omega_{jt}$ (for $i, j = 1, 2$), Johansen (1988) shows that the likelihood ratio test statistic for the hypothesis of at most r equilibrium relationships is given by:

$$-2lnQ_r = -T \sum_{i=r+1}^{p} ln(1 - \lambda_i) \tag{7}$$

where $\lambda_1 > \lambda_2 > ... \lambda_p$ are the eigenvalues that solve the following equation:

$$/ \lambda S_{22} - S_{21} S_{11}' S_{12} / = 0. \tag{8}$$

The eigenvalues are also called the squared canonical correlations of ω_{2t} with respect to ω_{1t}. The limiting distribution of the $-2lnQ_r$ statistic is given in terms of a $p - r$ dimensional Brownian motion process, and the quantiles of the distribution are tabulated in Johansen & Juselius (1990) for $p - r = 1, ..., 5$ and in Osterwald-Lenum (1992) for $p - r = 1, ...10$. Equation (7) is usually referred to as the trace test statistic which is rewritten as follows:

$$L_{trace} = -T \sum_{i=r+1}^{p} ln(1 - \lambda_i) \qquad (9)$$

where $\lambda_{r+1}, \ldots \lambda_p$ are the $p - r$ smallest squared canonical correlation or eigenvalue. The null hypothesis is at most r cointegrating vectors. The other test for cointegration is the L-maximal eigenvalue test based on the following statistic:

$$L_{\max} = -T.ln\,(1\text{-}\lambda_{r+1}) \qquad (10)$$

where λ_{r+1} is the $(r + t)^{\text{th}}$ largest squared canonical correlation or eigenvalue. The null hypothesis is r cointegrating vectors, against the alternative of $r + 1$ cointegrating vectors. By comparing the two tests, Johansen & Juselius (1990) indicated that the trace test may lack power relative to the maximal eigenvalue test which will produce clearer results.

2.3 Sources of Data

Drawing on the suggestion by Cherry & List (2002), we used disaggregate data on crime. According to Cherry & List (2002, p.81), "it is inappropriate to pool crime types into a single decision model and that much of the existing empirical evidence suffers from aggregation bias." Since we recognize that the deterrence effect of unemployment is quite heterogeneous across crime types, for this study, we have disaggregated crime offences into 15 sub-categories of crime, that is, violent and property crimes, namely: murder, attempted murder, gang robbery with firearms, gang robbery without firearms, robbery with arms, robbery without arms, rape, assault, day house burglary, night house burglary, lorry-van theft, car theft, motorcycle theft, bicycle theft and other theft. In fact, earlier studies by Cherry (1999) and Cornwell & Trumbull (1994) have pointed out that unobserved heterogeneity in the unit of observation may lead to spurious relationships that incorrectly imply or exaggerate deterrent effects.

Data on crime and their sub-categories for the period of 1973 to 2005 were collected from the Royal Police of Malaysia (PDRM). The total criminal activities are classified into 15 categories: murder, attempted murder, gang robbery with firearms, gang robbery without firearms, armed robbery, robbery without firearms, rape and assault (these comprise the violent crime); day house burglary, night house burglary, lorry-van theft, car theft, motorcycle theft, bicycle theft and other theft (these comprise the property crime). All crime rates were measured based on 100,000 population. The number of police personnel was used as a proxy for police strength. All variables were transformed into natural logarithm.

3. THE EMPIRICAL RESULTS

3.1 Results for Total Crime Rate, Violent Crime Rate and Property Crime Rate

Before testing for cointegration by using the Johansen-Juselius procedure, we test for the order of integration of all variables for all crime rates. Table 1 shows the results of the unit root test used to determine the order of integration of police, total crime, and violent and property crime rates. Clearly, in all cases, the augmented Dickey-Fuller test (Dickey & Fuller, 1981) statistics indicate that the four series are difference stationary; in other words, they are $I(1)$ in levels.

Table 1. Results of unit root tests for total, violent and property crime index

Criminal activities	ADF unit root tests	
	Levels	First-differences
Total crime	–2.50 (1)	–3.60**(0)
Violent crime	–2.91 (1)	–4.05**(0)
Property crime	–2.43 (1)	–3.60**(0)
Police	–2.32 (0)	–5.10**(0)

Note: Asterisk (**) denotes statistical significance at the 5% level. Critical values are taken from MacKinnon (1996). Series in levels were estimated with constant and trend, while series in first-differences were estimated with constant only. Figures in parentheses denote lag length chosen by SBC criterion.

Having noted that both (crime and police) series are of the same order of integration, we ran the cointegration test following the procedure provided by Johansen & Juselius (1990). These results are tabulated in Table 2. The null hypothesis of no cointegration can be rejected in all three cases of the crime-police nexus using both the trace and L-max statistics at the 5% significance level. This result implies that there is no long-run relationship between the three crime categories and police personnel in Malaysia for the period of 1973 to 2005.

Table 2. Results of bi-variate cointegration tests (VAR = 2)

Criminal activities	Null hypothesis	Trace test	Lamda-max test
Total crime	H_0: r = 0	7.46	6.83
	H_0: r = 1	0.63	0.63
Violent crime	H_0: r = 0	12.23	11.95
	H_0: r ≤ 1	0.28	0.28
Property crime	H_0: r = 0	7.80	7.01
	H_0: r ≤ 1	0.79	0.79

Note: Asterisk (**) denotes statistical significance at the 5% level. Critical values are taken from MacKinnon-Haug-Michelis (1999).

Nevertheless, knowing that the Johansen-Juselius cointegration procedures are distorted in small samples, we prefer employing the vector error-correction model to infer cointegration among the series. As a matter of fact, according to the Granger Representation Theorem (Engle & Granger, 1987), not only does cointegration imply the existence of an error-correction model but also that the converse applies, that is, the existence of an error-correction model implies cointegration of the variables. Recent developments in cointegration and error-correction model as pointed out by Pesavento (2004) suggest that the Johansen's test for cointegration has low power in both large and small samples compared to the error-correction model. In fact, Kremers, Ericsson & Dolado (1992) have argued that the standard t-ratio for the coefficient on the error-correction term in the dynamic equation is a more powerful test for cointegration. Banerjee, Dolado, Hendry & Smith (1986) and Kremers *et al*. (1992) show that standard asymptotic theory can be used when conducting the test in the context of an error-correction model; specifically, the t-statistics on the error-correction term coefficients have the usual distribution.

Therefore, we specify the following two-variable vector error-correction models (VECM) as:

$$\Delta y_t = a_0 + \sum_{i=1}^{k} \alpha_i \Delta y_{t-i} + \sum_{j=1}^{k} \alpha_j \Delta x_{t-j} + \gamma_1 ecm_{t-1} + \varepsilon_{1t} \quad (11)$$

$$\Delta x_t = b_0 + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \sum_{j=1}^{k} \beta_j \Delta x_{t-j} + \gamma_2 ecm_{t-1} + \varepsilon_{2t} \quad (12)$$

where ecm_{t-1} is the lagged residual from the cointegration between y_t (say, crime) and x_t (police) in level. Granger (1988) points out that based on equation (11), the null hypothesis that x_t does not Granger cause y_t is rejected not only if the coefficients on the x_{t-j} are jointly significantly different from zero, but also if the coefficient on ecm_{t-1} is significant. The VECM also provides for the finding that x_{t-j} Granger cause y_t, if ecm_{t-1} is significant even though the coefficients on x_{t-j} are not jointly significantly different from zero. Furthermore, the importance of α and β are that they represent the short-run causal impact, while γ gives the long-run impact. In determining whether y_t Granger causes x_t, the same principle applies with respect to equation (12). Above all, the significance of the error-correction term (ecm) indicates cointegration, and the negative value for γ suggests that the model is stable and any deviation from equilibrium will be corrected in the long run.

The results of estimating equations (11) and (12) are presented in Table 3. From the VECM results in Table 3, we present the *t*-statistics of the error-correction term, ecm_{t-1} where we can infer the long-run causality between the variables. The significance (at least one) of the error-correction term at the 5% level implies cointegration or exhibits long-run relationship between crime and police force. In other words, both these two variables are bound together by the long-run relationship. The results also suggest that *Granger* long-run causality runs from police to total crime and property crime. For the violent crime, *Granger* long-run causality runs from violent crime to police.

Table 3. Results of long-run relationship between crime and police personnel

Criminal activities	Dependent variable	t-statistics of ecm_{t-1} in VECM model
Total crime	ΔTotal crime	–2.32**
	ΔPolice	–0.94
Violent crime	ΔViolent crime	–1.69
	ΔPolice	–2.97**

Table 3 (con't)

Criminal activities	Dependent variable	t-statistics of ecm_{t-1} in VECM model
Property crime	ΔProperty crime	–2.45**
	ΔPolice	–0.67

Note: Asterisk (**) denotes statistical significance at the 5% level.

Our main interest is to determine the sign and size of the long-run (elasticities) parameter estimates, α_1, in equation (1). The result of the long-run elasticities of crime rate responses to changes in the police force is given in Table 4. The result indicates that only in the case of violent crime is the police significantly different from zero. The result suggests that a 1% increase in the police strength will reduce violent crime rates by 1.2%. As for total crime and property crime, the police have no effect on crime rates in Malaysia.

Table 4. Results of long-run elasticities

Criminal activities	The long-run model
Total crime	$11.598 - 0.8859(1.5516)police_t$
Violent crime	$11.010 - 1.1655^{**}\ (2.3488)police_t$
Property crime	$11.044 - 0.8164(1.4587)police_t$

Note: Asterisk (**) denotes statistical significance at the 5% level.

3.2 Results for Disaggregated Crime Categories

The results pertaining to all 15 sub-categories of crime in Malaysia are reported in Tables 5 to 8. In Table 5, we report the results for the order of integration for the sub-categories of criminal activities, which suggest that except for murder and rape, all other crime rates are integrated of order one at the 5% level. However, at the 1% level, we can safely say that both murder and rape are also integrated of order one. Therefore, we conclude that all the 15 sub-categories of crime in Malaysia are I(1) time-series variables.

Table 5. Results of unit root tests for the disaggregate crime activities

Criminal activities	ADF unit root tests	
	Levels	First-differences
Violent crime		
Murder	–3.80**(0)	–6.88**(0)
Attempted murder	–2.58 (0)	–7.37**(0)
Gang robbery with firearms	–2.58 (0)	–5.80**(0)
Gang robbery without firearms	–1.91 (1)	–4.59**(0)
Armed robbery	–2.49 (0)	–5.53**(0)
Robbery without arms	–2.42 (1)	–4.53**(0)
Rape	–3.60**(1)	–5.61**(0)
Assault	–2.68 (1)	–4.38**(0)

Table 5 (con't)

Criminal activities	ADF unit root tests	
	Levels	First-differences
Property crime		
Day house burglary	3.38 (1)	–3.55**(0)
Night house burglary	–2.22 (6)	–3.63**(0)
Lorry-van theft	–2.78 (0)	–5.49**(0)
Car theft	–3.24(7)	–4.42**(0)
Motorcycle theft	–2.38 (1)	–3.96**(0)
Bicycle theft	–1.71 (0)	–6.03**(0)
Other theft	–3.26 (5)	–2.96**(7)

Note: Asterisk (**) denotes statistical significance at the 5% level. Critical values are taken from MacKinnon (1996). Series in levels were estimated with constant and trend, while series in first-differences were estimated with constant only. Figures in parentheses denote lag length chosen by SBC criterion.

Table 6 shows the result of the cointegration test between police and the crime rates for each sub-category. The null of no cointegration can be rejected in 11 out of 15 categories. Long-run relationships are shown between the police and murder, attempted murder, gang robbery with firearms, armed robbery, robbery without arms, rape, assault, day house burglary, motorcycle theft, bicycle theft and other theft. For motorcycle theft, based on the trace test, the null hypothesis of no cointegration can be rejected. According to Cheung & Lai (1993), the trace test shows more robustness to both skewness and excess kurtosis in the residuals than does the L-max test; therefore, we can emphasise on the use of trace statistics to make inferences for non-cointegration between other theft and the police in this study.

Table 6. Results of bi-variate cointegration tests (VAR = 2)

Criminal activities	Null hypothesis	Trace test	Lamda-max test
Violent crime			
Murder	H_0: r = 0	20.55**	18.18**
	H_0: r ⩽ 1	2.36	2.36
Attempted murder	H_0: r = 0	25.13**	23.18**
	H_0: r ⩽ 1	1.95	1.95
Gang robbery with firearms	H_0: r = 0	38.73**	36.17**
	H_0: r ⩽ 1	2.56	2.56
Gang robbery without firearms	H_0: r = 0	10.60	10.60
	H_0: r ⩽ 1	0.00	0.00
Armed robbery	H_0: r = 0	17.87**	16.88**
	H_0: r ⩽ 1	0.98	0.98

Table 6 (con't)

Criminal activities	Null hypothesis	Trace test	Lamda-max test
Robbery without arms	H_0: r = 0	10.19	10.16
	H_0: r ≤ 1	0.02	0.02
Rape	H_0: r = 0	23.92**	23.60**
	H_0: r ≤ 1	0.31	0.31
Assault	H_0: r = 0	18.28**	16.34**
	H_0: r ≤ 1	1.93	1.93
Property crime			
Day house burglary	H_0: r = 0	17.02**	16.44**
	H_0: r ≤ 1	0.58	0.58
Night house burglary	H_0: r = 0	9.48	7.66
	H_0: r ≤ 1	1.82	1.82
Lorry-van theft	H_0: r = 0	21.28**	21.26**
	H_0: r ≤ 1	0.02	0.02
Car theft	H_0: r = 0	14.13	14.00
	H_0: r ≤ 1	0.12	0.12
Motorcycle theft	H_0: r = 0	14.45	14.34**
	H_0: r ≤ 1	0.11	0.11
Bicycle theft	H_0: r = 0	18.69**	15.50**
	H_0: r ≤ 1	3.19	3.19
Other theft	H_0: r = 0	21.06**	19.56**
	H_0: r ≤ 1	1.50	1.50

Note: Asterisk (**) denotes statistical significance at the 5% level. Critical values are taken from MacKinnon-Haug-Michelis (1999).

Despite having shown 11 sub-categories of crime rates that are cointegrated between crime and police by using the Johansen multivariate cointegration test, we further infer the long-run relationship from the ECM framework as suggested by Pesavento (2004), Kremers *et al.* (1992) and Banerjee *et al.* (1986). The results of the error-correction model estimations are presented in Table 7. Interestingly, in all cases, the error-correction term is significantly different from zero at the 5% level. Thus, we conclude that there is a long-run relationship between all the 15 sub-categories of crime rates and police personnel in Malaysia for the period of 1973 to 2005. The significance of the ECM term indicates that one-way Granger long-run causality runs from police to gang robbery with firearms, armed robbery, day house burglary, night house burglary and other theft. On the other hand, a one-way Granger long-run causality runs from attempted murder, gang robbery without firearms, robbery without arms, rape, lorry-van theft, car theft, motorcycle theft and bicycle theft to police personnel. A bi-directional Granger long-run causality is detected in the cases of murder and assault, and police personnel.

Table 7. Results of long-run relationship between crime and police personnel

Criminal activities	Dependent variable	*t*-statistics of ecm_{t-1} in VECM model
Violent crime		
Murder	ΔMurder	–2.34**
	ΔPolice	–3.11**
Attempted murder	ΔAttempted murder	–1.45
	ΔPolice	3.45**
Gang robbery with firearms	ΔGang robbery with firearms	–7.37**
	ΔPolice	–0.91
Gang robbery without firearms	ΔGang robbery without firearms	–1.49
	ΔPolice	–2.11**
Armed robbery	ΔArmed robbery	–3.01**
	ΔPolice	1.50
Robbery without arms	ΔRobbery without arms	–1.46
	ΔPolice	–2.65**
Rape	ΔRape	–1.44
	ΔPolice	–5.29**
Assault	ΔAssault	–2.82**
	ΔPolice	–3.19**
Property crime		
Day house burglary	ΔDay house burglary	–3.75**
	ΔPolice	–1.56
Night house burglary	ΔNight house burglary	–2.61**
	ΔPolice	–0.37
Lorry-van theft	ΔLorry-van theft	–0.53
	ΔPolice	–4.88**
Car theft	ΔCar theft	–0.33
	ΔPolice	–3.28**
Motorcycle theft	ΔMotorcycle theft	–1.39
	ΔPolice	–3.15**
Bicycle theft	ΔBicycle theft	–0.63
	ΔPolice	3.79**
Other theft	ΔOther theft	–3.98**
	ΔPolice	0.88

Note: Asterisk (**) denotes statistical significance at the 5% level.

The long-run impact of police on crime rates is shown in Table 8. As shown in Table 8, the estimated long-run coefficient or elasticities (α_1) are significantly different from zero at least at the 5% level. Only in the cases of robbery without arms and other theft, do the police have impact on the crime rates at the 10% level. Nevertheless, police personnel have no effect on day house burglary in Malaysia. Of the 14 types of crimes, police presence impacted negatively on crime rates in 8 out of the 14 types: murder, gang robbery without firearms, robbery without arms, rape, assault, lorry-van theft, car theft and motorcycle theft. On the other hand, police impacted positively on attempted murder, gang robbery with firearms, armed robbery, night house burglary, bicycle theft and other theft. The responses of crime rates to a 1% change in police personnel is a reduction in crime rates that ranges from 0.5% in the case of murder to 5.8% in the case of lorry-van theft. On the other hand, the responses of crime rates to a 1% change in police personnel is an increase in crime rates that ranges from 0.4% in the case of other theft to 3.0% in the case of armed robbery.

Table 8. Results of long-run elasticities

Criminal activities	The long-run model
Violent crime	
Murder	$3.8987 - 0.5217$ ** $(3.7907) police_t$
Attempted murder	$-6.7119 + 0.9109$ ** $(2.4521) police_t$
Gang robbery with firearms	$-6.9779 + 0.9515$ ** $(5.7187) police_t$
Gang robbery without firearms	$20.098 - 3.1189$ ** $(3.1529) police_t$
Armed robbery	$-17.316 + 3.0587$ ** $(5.6952) police_t$
Robbery without arms	$11.112 - 1.2626(1.7334) police_t$
Rape	$13.476 - 1.9978$ ** $(6.1820) police_t$
Assault	$8.1403 - 0.8857$ ** $(2.9399) police_t$
Property crime	
Day house burglar	$5.7707 - 0.3978(1.2101) police_t$
Night house burglary	$-0.5061 + 0.8357$ ** $(2.4858) police_t$
Lorry-van theft	$37.071 - 5.8796$ ** $(6.1471) police_t$
Car theft	$17.072 - 2.3591$ ** $(2.9049) police_t$
Motorcycle theft	$25.279 - 3.4484$ ** $(3.7116) police_t$
Bicycle theft	$-12.857 + 2.6431$ ** $(2.3718) police_t$
Other theft	$2.2347 + 0.4797(1.8218) police_t$

Notes: Asterisk (**) denotes statistical significance at the 5% and 10% level respectively.

4. CONCLUSION

The purpose of the present study is to investigate the long-run and causal relationship between police personnel and 15 categories of criminal activities in Malaysia for the period of 1973 to 2005. In this study, we employed the Johansen multivariate cointegration test and the error-correction model framework to infer cointegration between crime rates and police personnel. We investigated several measures of crime rates at both the aggregated and disaggregated level: total crime, and violent and property crime rates. The sub-categories of crimes are namely: murder, attempted murder, gang robbery with firearms, gang robbery without firearms, armed robbery, robbery without arms, rape, assault, day house burglary, night house burglary, lorry-van theft, car theft, motorcycle theft, bicycle theft and other theft.

Our long-run model suggests that police personnel have a negative effect on violent crime, murder, gang robbery without firearms, robbery without arms, rape, assault, lorry-van theft, car theft and motorcycle theft, thus supporting Becker's crime model. On the other hand, positive effect of police personnel on crime is supported in the cases of attempted murder, gang robbery with firearms, armed robbery, night house burglary, bicycle theft and other theft. We contend that the positive effect of police personnel on crime would support the "long-run natural rate of crime" hypothesis.

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