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TECHNICAL REPORT

Testing the Police Workforce Resilience Hypothesis

An application of labour economics to policing management

Priscillia Hunt, Barrie Irving, Luca Farnia

Prepared for the Workforce Programmes Unit of the National Policing Improvement Agency

RAND EUROPE

The research described in this report was prepared for the Workforce Programmes Unit of the National Policing Improvement Agency.

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Preface

The UK Home Office (HO) has general responsibility for governmental oversight of police forces in England and Wales. Although this executive authority does not include responsibility for 'operational' decisions taken by Chief Officers, the Home Office is responsible for police force efficiency and effectiveness and controls most of the policing budget. The HO is assisted in these matters by the National Policing Improvement Agency (NPIA), which provides science, technology, training, education and research. The NPIA has a Workforce Programmes Unit charged with developing a ten year workforce plan, built upon findings of the National Workforce Modernisation (WFM) Programme.[1]

The National WFM Programme identified challenges regarding police force capacity and capability to cope with demands for day-to-day policing and policing of national imperatives, such as the 2012 Olympics. This study clarifies key concepts in policing workforce management and quantifies the relationship between police force human resource levels and composition and demand for policing. By employing an innovative and novel econometric approach, we are able to estimate the number of police officers needed to control crime.

This study starts with an introduction to the workforce programme and resiliency issues facing the police forces in England and Wales. We then build a framework to understand the ability of the police service to meet demands for policing as changes are made in the level and composition of its workforce. We pay particular attention to the relationship between police officers and police staff. We then provide empirical evidence regarding the number and composition of the workforce to meet different levels of demand. The report concludes with a discussion of data and knowledge gaps.

This report was produced with funding support from the NPIA on behalf of the Workforce Programmes Unit. The report will be of interest to police managers, strategists and policy makers, and national and local government officials responsible for police workforce issues and service delivery. Specifically, it will contribute to the development of the UK Government's objectives on sustainable public order, a cause which is shared by a number of other jurisdictions.

RAND Europe is an independent not-for-profit policy research organisation that aims to serve the public interest by improving policy making and informing public debate. Its

[1] http://police.homeoffice.gov.uk/human-resources/efficiency-and-productivity/workforce-modernisation-programm/index.html.

clients are European governments, institutions and firms with a need for rigorous, impartial, multidisciplinary analysis.

This report has been peer-reviewed in accordance with RAND's quality assurance standards.

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Abbreviations

ACPO	Association of Chief Police Officers of England, Wales and Northern Ireland
ADL	Autoregressive Distributive Lag
BCS	British Crime Survey
DW	Durbin-Watson
FORM	RAND Europe's Factors of Resilience Mapping framework
IT	Information Technology
JIT	Just-in-time
NHS	National Health Service
OLS	Ordinary Least Squares
ONS	Office for National Statistics
PSA	Public Service Agreement
UK	United Kingdom
US	United States

Executive summary

Introduction

An issue high on the national policy agenda is how to reduce the ever-expanding expense of the police service while maintaining its ability to respond in an appropriate and timely manner to both routine and extraordinary situations. In other words, there is a priority quest for cost-effective policing resilience.

Police forces are expected to be prepared for and cope with exceptional events, such as violence across the Olympic parks or terrorist threats; routinely to reassure the public that their community is safe and secure, and to investigate and prevent local volume crime, as well as organised crime both nationally and internationally. There can be severe consequences if police forces fail to respond effectively, whatever the demand.

Spending on police has grown in real terms from £9.8bn in 1999 to £14.5bn in 2009 with over 75 per cent attributable to workforce costs (Mills et al., 2010). Police, in common with all public services, now face severe budget cuts that are bound to involve reducing workforce costs. This immediately raises practical issues about resilience: can a tipping point, either in overall numbers or in the exact composition of the workforce, be discerned after which resilience will be in jeopardy?

In order to help police forces cope with the coming constraints on their budgets while planning for the future, tools need to be developed that will help the service address the resilience question. More generally the service needs a model of the way in which demand for policing and police workforce size and composition interact. Such a model should allow police managers to determine what the effect of different levels and kinds of cuts will be on their ability to meet projected demand in an effective manner. It is our understanding that such a tool does not exist.

The objectives of this study are to examine what constitutes resilience and its component parts and to provide qualitative and quantitative tools to assist policy makers, chief constables, police authorities and local government officials in police workforce management.

Approach

Through qualitative and quantitative methods, this report reviews the primary elements of police work – police workforce resources, the demand for policing and the risk of failure to deliver services – and the ways in which these elements interact to produce resilience. We take an innovative approach in our review of the issues by building two tools that will assist the police service in its workforce management.

We produce a conceptual framework to be known as the Factors of Resilience Mapping (FORM) framework, which is a qualitative tool to support a more systematic discussion of policing demands and workforce levels. The FORM framework allows us to identify the appropriate theoretical model, which can be estimated to quantify states of resilience. The theoretical model we identify is one from biology – the predator–prey model – and we use the model to find: the level to which police officer numbers would have to rise to eliminate crime; the level to which crime would be likely to rise with no police officers; and the long-run level of crime and police officers, as an accommodation is gradually reached between the two previous extremes (of no crime and no officers).

Main findings and future research directions

This report examines issues surrounding resilience in policing and advances the following findings:

- A model borrowed from biology, the predator–prey model, best describes the way crime and police workforce size have been working towards accommodation. England and Wales are currently in the phase of the police-crime cycle in which a past abundance of crime (the prey of the model) encouraged significant growth of police numbers (predator population level). It takes up to three years for police workforce size to adjust to the level of crime. While simple descriptive statistics seem to support the much quoted apparent lack of relationship between police labour force size and demand for policing, more sophisticated econometric analyses indicate this is because there are lagged effects. Findings, therefore, suggest police workforce planners have tended to chase rising crime trends without suitable adjustments for lagged effects and trend reversal. They may want to consider other more nuanced strategies for addressing demand in policing, especially under current fiscal conditions.

- As to specific numbers, we find that by using the predator–prey model as a basis for estimation, the demand and supply for policing in England and Wales will reach a balanced accommodation when there are approximately 130,000 police officers and approximately 5 million crimes a year. This represents a 9 per cent rise in crime and a 7 per cent fall in police workforce numbers based on 2009 levels.

- The optimal ratio of police officers to police staff cannot currently be determined. There are insufficient long-run data on the composition of forces and their outputs to be able to come to any useful conclusions on this issue. In particular it is not known how many additional full time equivalent police workforce members can be created by using Special Constables, overtime provisions, mutual aid and temporary changes in contracts to boost workforce levels for short periods to cope with exceptional demand.

As with any research endeavour, there are limitations to the findings. The main constraints in this research are related to data. We use 15 years of data on police officers and staff numbers and the number of recorded crimes. Results therefore may need to be treated with some caution. Results would be improved with more years of data on police workforce numbers and data across police force areas over time. Moreover, we use the number of crimes recorded to represent the supply and demand for policing. Recorded crime does not necessarily capture all crimes that occur, nor does it represent the demand to prevent

crime. As noted above, there are also no usable data on the various ways in which extraordinary demand can be met by extraordinary coping mechanisms.

Estimates of the numbers of police officers and staff and the number of crimes for the extreme states of resilience are achieved by mathematical extrapolation from existing data using the predator–prey model to guide calculations; the steady state point on the resilience curve is also estimated by using the predator–prey model, which appears to be the most appropriate available. All estimates have been checked and tested as far as existing available data allow. However, the testing process needs to continue and will inevitably lead to refinement of the estimates.

Future research directions

In a democracy that polices with consent, a key element of policing performance is to deliver the type and level of policing that the public want. Local assessment of delivery is currently problematic: the required attitude surveys are very expensive and difficult to manage effectively. Much of the available information on public satisfaction with policing data is of dubious quality. There is an obvious need to tackle this deficit. Little is known about how local police commanders and the populations they police assess the risk of police failure to cope. It could be that both police managers and public fear the same kind and level of breakdown; however, that may not be so. Even if police and public share the same concept of threat, they may disagree about the gravity of given threats and groups of threats. This gap in our knowledge also needs to be filled in order to cope properly with concerns about resilience.

The effect of workforce composition on resilience remains a significant unanswered question. To answer it, much more needs to be known about workforce composition under routine and extraordinary operational conditions. We need to progress from using relatively crude estimates such as total workforce numbers to accounting for all the ways in which local commanders and managers of the Association of Chief Police Officers of England, Wales and Northern Ireland (ACPO) can bolster resources in any department suffering overload. Only then can we isolate the particular effect on operational efficiency of the ratio of police officers to police staff.

This report suggests that across England and Wales the number of police officers and staff could be reduced by 7 per cent without disturbing the accommodation process between crime and police workforce size represented within the model. However, a one-size-fits-all strategy of reducing every police force by 7 per cent is not implied. More research is needed into how our estimation process works out in each of the 43 police force areas before local recommendations can be made. That detailed level of analysis was beyond the scope of this research, but it is a natural follow-on from this project. At force level it will be possible to take into account much more detailed information about fluctuations in workforce level, composition and outputs.

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All errors in this document are those of the authors.

CHAPTER 1 Introduction

1.1 The Workforce Modernisation Programme

In April 2007, the National Policing Improvement Agency (NPIA) was formed "to make a unique contribution to improving public safety".[2] With policing being seen as an integral part of achieving public safety and order, the NPIA is considered a part of the police service.

The NPIA is officially responsible for managing the National Workforce Modernisation Programme (WFM) – a programme designed to "help the police service improve the quality of service it delivers to the public while delivering value for money".[3] The general concept of workforce modernisation was developed in the early 2000s. The intention was to improve the quality of policing while at the same time, if possible, reducing overall costs. It is a broad concept linking changes in the mix and level of human resources to outputs of the police service. Launched in 2007, the National WFM Programme included a series of activities to enhance the capability of police to improve public safety and order (effectiveness) or increase or maintain services at a lower cost (efficiency).

Workforce Modernisation investigations and research suggest that overall WFM policing objectives will be met by a reduction in police officers[4] and an increase in police staff. According to the NPIA, the reason is that police work has been traditionally configured in such a way that police officers perform a wide range of tasks for which a high level of skills and experience and in some cases warranted policing powers are unnecessary. Re-arranging roles and responsibilities to allow police officers to concentrate on tasks that require their skills and training can cut costs and maintain or even enhance effectiveness.

However, all those involved in police management understand that police officers have one significant advantage over police staff when the service has to respond to extraordinary levels of demand – they are neither subject to the same employment contracts nor to the restrictions imposed on deployment by ordinary labour law. Therefore they provide managers with the utmost flexibility in meeting extraordinary demands for service.

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[2] http://www.npia.police.uk/en/5151.htm

[3] The UK National Audit Office, the body responsible for auditing the government on value for money, describes value for money as "the economy, efficiency and effectiveness of public spending". See http://www.nao.org.uk/about_us/what_we_do/value_for_money_audit.aspx

[4] Police officers have warranted powers.

Given the foreseeable reduction in police officers relative to police staff, there are concerns that the police workforce will not have the capacity and capability to deliver appropriate, timely and sustainable services. This loss of capacity and capability is now generally referred to as 'police resilience'.

1.2 The 'Resilience Hypothesis'

The National WFM Programme has thus far included pilot testing of ideas to improve value for money, evaluations of pilots, and other research in order to inform the NPIA of those activities that achieve higher value for money. The synthesis of this work led to the construction of an outline 'Resilience Hypothesis'.

Police resilience has been defined as: "having the capacity and capability[5] to provide an appropriate and sustainable response to a range of demands[6] within acceptable parameters of risk while optimising quality of service and efficiency" (TribalAvail, 2008, p. 2).

Police resilience links three key elements – demand for policing, risk of failure to meet demand, and police resources — to meet demand. The NPIA has been considering the relationships between these three key elements of resilience and has now formulated a preliminary hypothesis about the nature of resilience. This 'Resilience Hypothesis' states simply that "resilience comprises a relationship between demand, risk and resource" (NPIA, 2009). Early investigation of this hypothesis has thrown up critical questions: is there a tipping point where resources become unable to cope with policing demand and can an optimal ratio of police officers and staff be determined? NPIA has tried to address these questions and has tentatively concluded that the answers to both may be negative. We have been invited to examine how NPIA reached this position and suggest ways out of this blind alley, if they exist, by proposing an appropriate model of resilience based on existing economic theory.

We recognised immediately that efforts to develop a sophisticated resilience hypothesis and answer the key questions have been hampered by lack of firm definition. Definitions of resource, demand and risk have multiplied to fit particular situations. With the elements of the resilience equation so ill-defined, they are too open to interpretation and the equation can be transformed in any way that suits those using it. Since the elements can always be re-defined, those involved in police workforce planning do not have a clear and concise way for thinking about what constitutes resilience and whether they are achieving it.

For example, in the police service, the 'risk' of failing to be resilient has historically been both an input to policing (via senior officers' subjective decision making) and an output of policing (via a level of service deemed to be acceptable). The problem with this is that it is not clear whether risk refers to how police managers deal with risk or how the public respond to varying levels of service under different risk conditions.

The source of this ambiguity is that no concept of acceptable risk has been introduced into police strategic management and there are no clear benchmarks about standards of service.

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[5] Internally and through collaboration with partner organisations.

[6] Including typical requirements, predictable events and unpredictable incidents.

Instead, both of these concepts are bundled into the definition of resilience. This lack of independence between the key variables and lack of completeness in the conceptual mapping have to be overcome if a useful dynamic workforce model is to be produced.

Another problem identified by the NPIA is that the interaction between demand, resources and risk is not well formulated. There is no clear and concise way for thinking about how changing one element of resilience (particularly the resources) affects other elements. Again, if there are changes in resources, demand and/or risk, those responsible for resilience in the police service cannot be certain whether what ensues constitutes resilience or not. What tends to happen now is that managers and observers adjust their priorities or even re-define police work so as to maintain a balance between demand and resource. Historically, therefore, the service has always achieved resilience and appeared to be coping.[7]

This report tackles these problems by clarifying the elements of the 'Resilience Hypothesis' and providing a viable explanatory framework of the interactions of the elements. This report supplies the NPIA and Home Office with a tool to conduct future labour planning endeavours within the police service. It also serves as a basis for ongoing discussions with police managers, civil servants and politicians about how to reduce spending in the police service and yet maintain resilience. We construct resilience in a straightforward way to facilitate improvements in the efficiency and effectiveness of policing – a core objective of police management.

1.3 Structure of the report

The rest of this report is structured as follows. Chapter 2 develops the conceptual framework for resilience. In order to accomplish this, we develop the activity of policing through the principles of labour economics; discuss how elements of the framework work and how they interact with each other; and concretise the elements of the framework through discussions on measurement. In chapter 3, we estimate the levels of resources and demand associated with three states of resilience and we quantify the relationship between demand and the number of police officers and police staff. In the final chapter, we synthesise all the evidence and present conclusions. We also note the limitations of this research and make recommendations for future work. For readers who wish to explore the estimation process in more detail, there are two technical appendices.

[7] The best documented case of this phenomenon is the systematic reduction of police patrols in Thames Valley during the height of the miners' strike in 1985.

CHAPTER 2

Towards a conceptual framework of resilience in policing

In its present form, the 'Resilience Hypothesis' proposition creates something of a barrier to progress in the police service because its terms are generally unclear and not concrete enough to quantify the minimum number of police officers required to maintain resilience.

In this chapter, we go back to basics and discuss police resilience using the tools of labour economics and general research methodologies. We start by defining the research problem and then describe and concretise the elements of resilience. Furthermore, we present a visual representation of how these elements interact with each other to provide police workforce planners with a conceptual framework.

2.1 Key elements of resilience

Resilience is a complex 'portmanteau' idea about the coping capability of each police force. In order to break down its complexity, in this section, we briefly discuss resilience through its key components: resources, demand and risk.

2.1.1 Resources to deliver policing

The two resources in policing are labour and capital

Any enterprise will have the possibility of three resources – labour, land and capital. Labour is the enterprise's people, the human resource. Land is any physical land property, such as acres of farm land, owned by the enterprise. Lastly, capital is any assets, such as equipment, owned by the enterprise.

In order to deliver policing, the police service needs labour (e.g. police officers and police staff) and capital (e.g. police stations, cars and helicopters) and the land on which police facilities are built.

The labour costs of policing constitute over 75 per cent of the total and for that reason we shall not refer separately to capital and land costs in the analysis that follows. For our purposes the total costs of policing are practically synonymous with the labour costs.

Police human resources have a number of key characteristics. The training and levels of experience and expertise of police officers and police staff varies. Police resources therefore include the mix of means to deliver policing services, such as police officers, capital equipment, land, ancillary services and so on.

The levels of resources are not infinite; there are constraints on how much labour and capital the police force has. The constraints are budget and time – there is only so much funding the police force can receive and it takes time to deliver policing services so that even if budget constraints are not relevant, time constraints still operate.

2.1.2 Demand of policing services

Demand for policing services depends on the amount that the public is willing and able to pay

Policing has evolved to meet public demands for personal safety and freedom from the threat of crime and the shared public and state concern for maintaining order. In general terms, the fact that the public reacts negatively to the threat of crime and desires public safety and order means there is what economists would recognise as a need for policing – a service for which individuals are willing to pay.

Generally speaking, demand is the willingness and ability to pay for a good or service. Services provided by police range from combating the threat of terrorist violence, for example across the Olympic parks; reassuring the public that their community is safe and secure; and preventing and investigating local volume crime, as well as organised crime nationally and internationally.

Demand for police services could therefore be characterised as: the level and range of policing services the public desires and for which it is willing and able to pay.

A basic property of demand is that consumers are willing and able to purchase less when the price increases. In policing, the implication is that as the police service asks for more funding (or the cost of current service provision increases), the public will demand a lower amount of police service.

2.1.3 Risk in police resilience

The probability that policing services will not meet expectations is unknown

Risk is usually referred to as the chance that an entity will incur loss or injury. In policing, managers accept some level of risk that their force will not be able to deliver an amount or quality of service.

Those responsible for policing efficiency and effectiveness in government, the civil service and the police service tend to translate their concerns about resilience into a conventional attitude to risk that plays itself out in the arena of labour economics: do we have enough personnel of the right mix to be able to cope effectively with whatever comes our way, and can the budget stand whatever strain is imposed by maintaining this level of resilience?

When the policing budget is rising, risk-aversion in policing can be taken into account by purchasing more resources. If policing budgets start to decline, then risk-averse police managers will naturally turn to the question of how precisely to cut the workforce to achieve maximum savings for minimum loss of resilience.

We therefore define risk as: the probability that policing services are not administered in a timely, appropriate and sustainable manner.

On the basis of what we have heard and read we have concluded that there is no concept of acceptable risk levels in policing. For example, police managers do not routinely decide that *x* number of officers should be deployed in order to keep the risk of failing to respond

effectively to less than *x* per cent. It follows that there is no standard policy about the presentation of risk to the public either directly or through governance channels (police authorities, the Home Office, Her Majesty's Inspectorate of Constabulary and so on).

2.2 The problem with resilience

As our understanding of the elements of resilience and the way the term is used in policing have developed, so it has become apparent that the concept is being asked to cover more ground than is feasible and in the process it has become unnecessarily complex. The National WFM Programme team has identified a variety of issues that a conceptual framework would need to address (see Box 2.1 for more on how we tackle the resilience problem). These are:

- policing demand, daily and extraordinary
- resources capable of meeting demand, by type of resource
- risk of failing to meet demand, whether real or perceived
- the scope and character of extraordinary events
- the costs of resources to meet demand
- the variability of demand over time and space.

Beneath each of these neat concept names lurks a wealth of sub-concepts, the true complexity of the phenomena we wish to study. We can go on unpacking concepts and mapping possible relationships between demand, resources and risk to an ever increasing level of detail, but we will quickly realise that:

- The level of detail is becoming too great for our purposes.
- Even if we can imagine indicators for all the elements of demand, resources and risk we are generating, there is unlikely to be any readily available source of data for a variable at that level of detail.
- We will generate too many potential variables to be able to cope with all their possible interactions.
- There is not enough time and funding in this study to deal with at this level of detail.

The NPIA has already spotted that it is difficult to turn all these concepts around resilience into variables and thus produce a model that can be properly populated with reliable data – a more precise and parsimonious definition is required. Box 2.1 describes how we go about teasing out the main components of policing, which are essential to model and then assess resilience.

As a first step, we therefore restate the problem of resilience in this way: how can the optimum size and composition of the police workforce be determined so that its capacity and capability to meet predictable daily patterns of demand to stipulated standards of performance has a probability of failure no higher than *X* per cent and *Y* per cent in the case of unpredictable events of demand of magnitude *A*?

Box 2.1: Broadening the resilience problem and teasing out the main components

First and most important, it is impracticable to try and deal with the full complexity of the police service as an operating and political entity. The police as a production system needs to be described with a manageable number of variables. The definition of the key economic variables such as demand and resource needs to be stripped down to bare essentials and in a form that promotes measurement. It may be satisfying to have a multi-layered description of policing but that does not help if all the layers cannot be measured.

Secondly, we must move to a position where the relationships between variables can be calculated and the complex effects of groups of variables on each other can be described. It is only by achieving this level of variable specification and measurement that we can 'model' the service so that we can estimate how changes in one variable (perhaps the size of each category of labour) affects how the system as a whole works (the quality of outputs, for example detections or people brought to justice, or public satisfaction with policing).

2.3 Mapping of a conceptual framework of resilience

We have argued that the current problem with the concept of police resilience is the lack of a systematic framework and an overcomplicated level of detail. In this section, we address this by reframing the process of delivering policing by going through each major step of policing production in what we will call RAND Europe's Factors of Resilience Mapping (FORM) framework.

2.3.1 Activities of policing

Police have two roles – to be proactive and reactive

When a crime occurs or the possibility of a crime or disorder exists, there is a role for policing. Generally, research identifies the duality of the police role – providing both proactive and reactive policing to communities. For example, Drake and Simper (2003) use 1996–1999 data from a variety of sources in order to assess the efficiency of England and Wales' police forces and they demonstrate that "it is particularly important...to consider both the response/reactive functions of the police, such as solving crimes, and the proactive/preventive functions, such as crime prevention and repression and policies to reduce road traffic accidents" (p. 171).

This is further supported by research indicating that police provide two very different functions: prevention/protection and control (essentially ante hoc activities) and detection of crime and re-establishing public order and tranquillity after breakdowns (post hoc activities) – the more successful the ante hoc activity, the less the demand for post hoc policing.

The mix of proactive and reactive tasks has some known properties, but predictability is interrupted catastrophically by rare and extreme events that require extraordinary levels and/or mixes of response. We describe the known properties of policing in Table 1 below.

Table 1: Policing objectives, functions and activities

Objective	Functions	Activities
Maintain/increase public safety and tranquillity	• Prevent crime and disorder	• Reduce causes of crime and disorder • Promote a sense of community order and cohesion (visible patrol and traffic patrol)
Restore order and administer the law	• Restore public order and tranquillity when it breaks down • Provide justice for victims of crime	• Investigate crime and bring offenders to justice • Intervene in breakdowns of order (restoring the Queen's Peace) • Deal with traffic incidents • Provide assistance and support following civil emergencies of all kinds • Respond to emergency calls for assistance from individuals

Policing is a 'house of many mansions'. At the most general level, police react to public and state demand for policing services while carrying on a continuous effort to prevent crime and disorder. Both proactive (preventive) and reactive effort cover a wide spectrum of events from the serious and complex (e.g. murder investigation) to the simple and minor (e.g. notifying householders of windows left open during routine patrol).

We shall develop our conceptual framework by starting at the simplest level and elaborating in stages discussing each addition as we go. We start with Figure 2.1, below. Proactive and reactive policing sit at the centre of the framework. The ascending arrows represent resources, the descending arrows represent a variety of constraints on policing activity; the left hand arrow represents demand which activates policing and the right hand arrow output (policing delivered). We go on to describe what is implied by each of these arrows and some of the associations between them. We call the resulting structure RAND Europe's FORM framework to simplify further discussion.

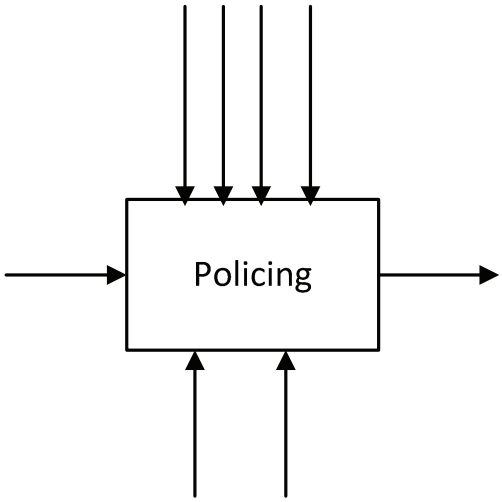


Figure 2.1: Policing activity in the FORM framework

2.3.2 Demand for policing services

Realised and potential crime and disorder generates a demand for policing

The occurrence of a crime or the threat of a potential crime drives individuals to demand policing services. The amount of demand for policing is shaped by the willingness and ability of the public to fund particular amounts of policing in a given time frame. That is, the public are *willing* to fund more policing if they feel more policing is necessary (the probability of a crime seems too high) and are *able* to fund more policing if it is affordable.

A 'demand shock' in the context of policing takes place when there is a sudden and unexpected change in the number or severity of crimes actually committed or expected (for a formal illustration of what a shock in police demand means, see Figure A.2). When an unexpected event occurs which has policing implications, the public's willingness to pay for policing may increase. This happens because these events (for example a terrorist attack or a series of murders) are likely to increase the public's fear of harm. This in turn raises the perceived value of policing services. Alternatively such events can increase the actual demand for policing, which puts pressure on the service to acquire or use more resources. So, as much as the public is willing to pay more, the police forces may cost more during an unexpected event. This higher cost can be due to the cost of labour (e.g. over-time) and/or the cost of capital (e.g. special equipment).

For the conceptual framework, we are therefore stating that a threat, actual or perceived, to individual or public safety sets up a demand for services from police forces with the authority to deliver such policing. This is illustrated below in Figure 2.2: Demand and policing in the FORM framework'. The main activity of policing (represented by a box) is initiated with an arrow entering the box from the left. A crime or potential crime drives the police to react or be proactive.

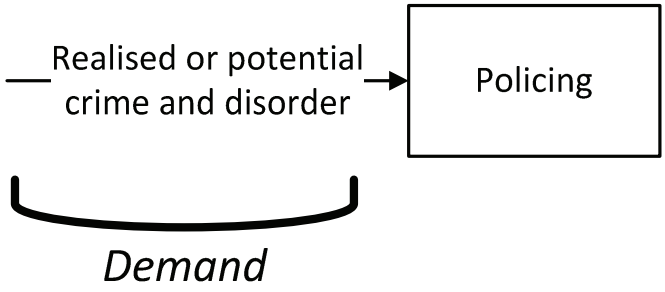


Figure 2.2: Demand and policing in the FORM framework

2.3.3 Resources for policing

Each additional officer is likely to deliver less policing than the one hired before

Policing can only be delivered by combining trained personnel and equipment, such as police cars, radio and IT systems. While private individuals and corporations[8] can purchase some forms of policing outside the service, they cannot purchase the capability of police officers.

In the RAND Europe FORM framework, arrows pointing upwards are resources to create policing (see Figure 2.3). As described earlier, both labour and capital are resources that are used to deliver policing services.

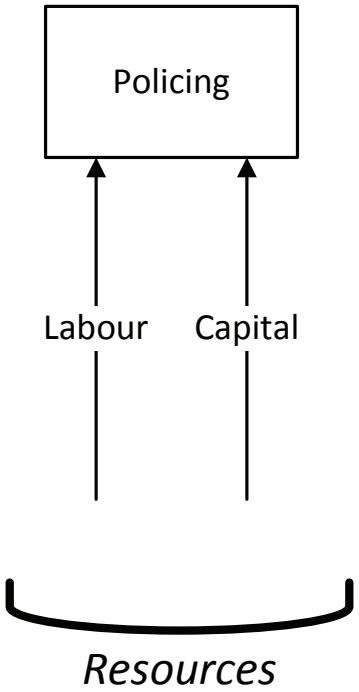


Figure 2.3: Resources and policing in the FORM framework

There is a key concept in economics that describes how resources interact with demand. It is the law of diminishing returns. This law describes how there are initially large output

[8] Such as policing of a privately funded event, for example a concert.

gains from the first few resources used (the first few police officers in a town with no police officers can introduce a great deal of policing). Eventually, however, each new unit of human resource produces less than the one before; in the typical enterprise, this is because a point will be reached where there are not enough capital resources for additional new units of human resource to use.

However, in the police service where the number of crimes to either prevent or detect may appear to be infinite, each new officer hired may appear to contribute as much or more than the last officer hired regardless of the state of capital resources. This may mean that the law of diminishing returns is not perceived as applicable to policing either by police managers, policy makers or the public. If a police force does not perceive diminishing returns, it will want to expand its workforce indefinitely:[9] if there never comes a time when each additional worker produces or is seen to produce less than the person who previously joined, the force will always recruit more workers. For more on how this works, see Appendix A.

2.3.4 Constraints to providing policing

The police service uses overtime, labour laws, and mutual aid to lessen constraints

There are complex constraints to the activity of policing, such as the law and political pressures that influence policing activities and limit the way the need for policing is satisfied. Gyimah-Brempong and Gyapong (1988), for example, model the demand for officers by taking input prices (wages, cost of police capital equipment) as given, and then assume "police decision makers choose inputs to maximize the level of output given the budget constraint imposed by the political budgetary process".[10]

The budget for policing is not infinite. Police authorities approve forces' budgets taking into account the Home Office contribution determined by the funding formula and the local authority contribution determined by the Council Tax precept. As always, there is only so much time a police officer or staff member can work. Even if labour laws are ignored, there are only 24 hours in a day and an individual will inevitably have an actual maximum working day substantially below that absolute limit. Figure 2.4 shows constraints and policing in the FORM framework.

[9] Precisely this phenomenon was proposed by James Hart in 1981 in his plan for the first neighbourhood policing experiment. He described what he called a 'demand spiral' for policing in which each new police officer created public demand equal to her inputs – the job is therefore never done. More recently this insight has been refreshed by Martin Innes (2004) who has developed the idea of signal events and signal responses to describe how certain policing strategies might overcome the demand spiral. Innes' work builds on an earlier attempt to achieve the same thing (Goldstein, 1996).

[10] It will be apparent to UK readers that this refers primarily to US policing where policing budgets are set and paid for locally and the electorate have the power to remove the Chief of Police along with the responsible mayor and administration.

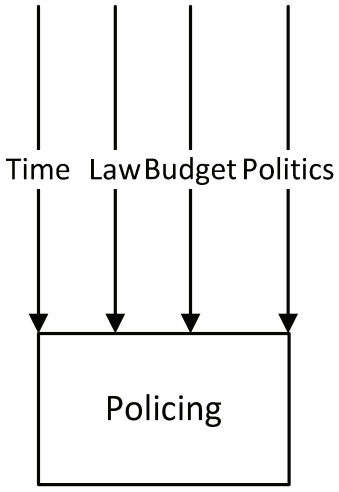


Figure 2.4: Constraints and policing in the FORM framework

Despite these constraints, the police service has made efforts to reduce the challenges posed by these constraints. These include:

1. *Hours of work.* In practice, there is the availability of overtime to get around the time constraints imposed on individual officers. The overtime rules and provisions are attractive to police officers and staff and overtime budgets are regularly overspent.[11]
2. *Contracts and labour laws.* Total access to each labour unit is theoretically controlled by contract type and labour legislation. In practice, however, managers have a good deal of leeway over short periods of time.
3. *Interdependence of forces.* Forces give mutual aid to one another under extreme circumstances to iron out the effect of extraordinary events.

2.3.5 Outputs of policing

Policing activities generate public safety and order and protection of individual rights

While the idea of producing a good or service is more normally associated with the private sector, there are parallels with the public sector – the public sector equally provides a good or service (output) with certain inputs (labour, capital) and is constrained (by budgets and time) to deliver the highest quality policing, health or education service possible.

Research tends to identify the output of policing to be one of crime control and prevention. Diez-Ticio and Mancebon (2002) review previous literature examining police production functions and they demonstrate the output of police is public safety and protection of the rights of individuals, with police seeking to maximise this output.

Smith et al. (2008) argue that "[a]n ideal system of crime control would be one that reduces crime as far as possible, that spreads the benefits of crime reduction as fairly as possible, but, in doing so, preserves the liberties (of movement, of privacy, and so on) that society deems to be essential" (p. 107).

[11] http://police.homeoffice.gov.uk/publications/human-resources/police-overtime2835.pdf?view=Binary

The quality of outputs can be captured in the measurement of output. For example, instead of number of crimes reduced, the police service can consider clearance rates. We discuss this in more detail later. Figure 2.5 shows outputs and policing in the FORM framework.

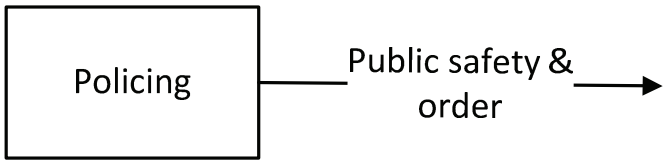


Figure 2.5: Outputs and policing in the FORM framework

2.3.6 Outcomes associated with policing

Public perception is an outcome of policing, not an output

Firms produce a good or service. When the good or service is well communicated and delivered to a customer, the outcome is overall customer satisfaction. Not all customers will be satisfied; firms accept that some customers have preferences that militate against satisfaction with their product. It is not beneficial to pursue improvements to products based on customers' dissatisfaction.

Firms do not produce customer satisfaction; it is an outcome of successfully delivering their outputs. Equally, police cannot produce customer satisfaction or improved public perception. They can attempt to improve the public's understanding of public safety and order either directly or through the media, and they can measure progress by improving the measurement of public perception. Good feedback can then be used to modify communication strategy. If police services improve but these outputs are not well communicated and/or public perceptions are inadequately assessed, then there will be no corresponding improvement in the public satisfaction outcome. It is also the case that the police service's best efforts to communicate successful outputs can be thwarted by the media and other agencies in pursuit of their own interests.

Public perception, or customer satisfaction, is only one possible outcome. Another more general outcome which avoids some of the pitfalls noted above is improved quality of life. In Figure 2.6 we represent the outcome in a circle following from the output, and adopt the label 'change in standard of living'.

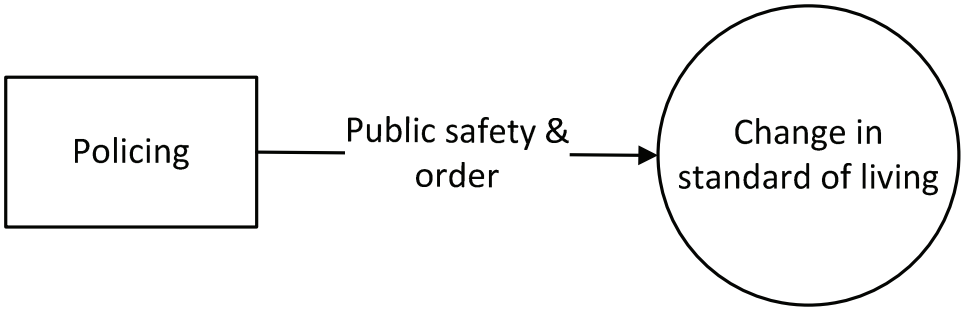


Figure 2.6: Outputs, outcomes and policing in the FORM framework

2.3.7 Risk of failure in the system

Some risks are perceived and not actual risks at all

The regular daily and seasonal flow of proactive and reactive demand for policing uses a fairly predictable mix of policing skills, experience, support services, equipment and so on. By definition adding to this background the occasional or more frequent unpredictable (chaotic) events creates an additional and unpredictable demand for police resources. In spite of their unpredictability and rarity, the chaotic events, by their nature, evoke very strong public emotions and political concern (e.g. air crashes, riots, terrorist attacks). In combination, political concern and public sensitivity fanned by an attentive media machine provoke a concern about the police service's ability to cope under extreme and extraordinary conditions.

The right mix of human resources for regular background policing demand may or may not be appropriate to cope with chaotic events. Tampering with the composition and scope (e.g. warranted powers) of the current labour resource generates concern among decision makers in policing (e.g. local police commanders and chief officers) because in general the police service believes the current level and mix of resource has coped historically and is 'fit for purpose'.

In other words, taking into consideration the conceptual framework, a reduction in the amount of resources or an unpredicted increase in demand may lead to disproportionate reduction in outputs (e.g. amount of public order and safety) and outcomes (e.g. standard of living). Therefore, as shown in Figure 2.7, risk in the context of resilience has to do with poor outputs and outcomes.

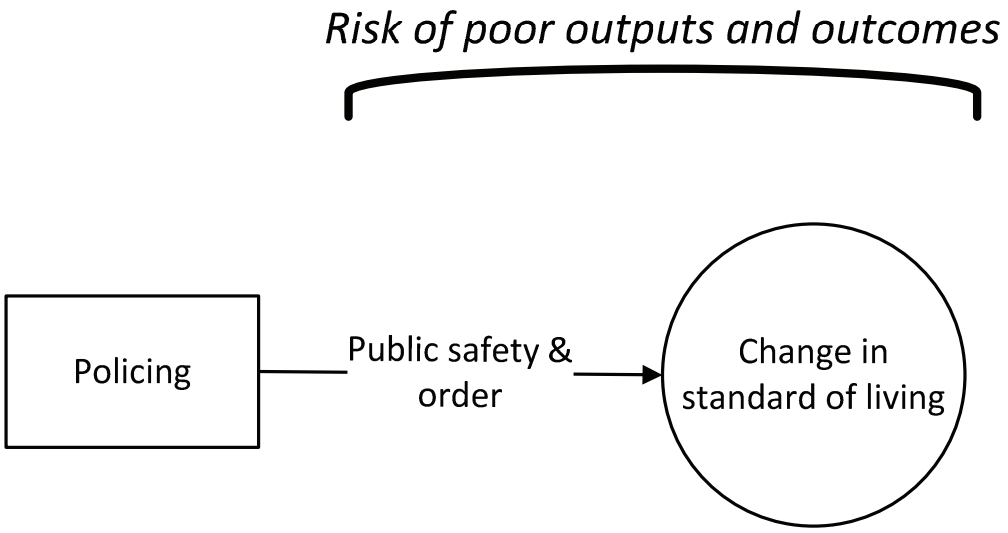


Figure 2.7: Risk and policing in the FORM framework

2.3.8 Full illustration of the conceptual framework

The RAND Europe FORM framework clarifies the complex issues of resilience

In the overall framework (Figure 2.8), the centre of the figure is the main activity of interest. For our purposes, the main activity is policing, both preventive and responsive as described earlier. The arrow pointing into the police activity is whatever initiates the need for policing, or the demand for policing; policing activity is initiated with a crime or disorder or a potential crime or disorder.

The main inputs, or resources, to generate the activity are arrows pointing upwards into the activity of policing. As noted earlier, these are labour (e.g. police officers) and capital (e.g. cars). Downward arrows represent constraints to deliver policing. There are a number of constraints to policing; we focus on two key constraints – legal and political pressures. Once the inputs and constraints are combined to make policing, the output of policing is public safety and order.

The final circle is the outcome of public safety and order. Crime and potential crime affects people's standard of living or quality of life. The aim of public safety and order is to improve individuals' standard of living.

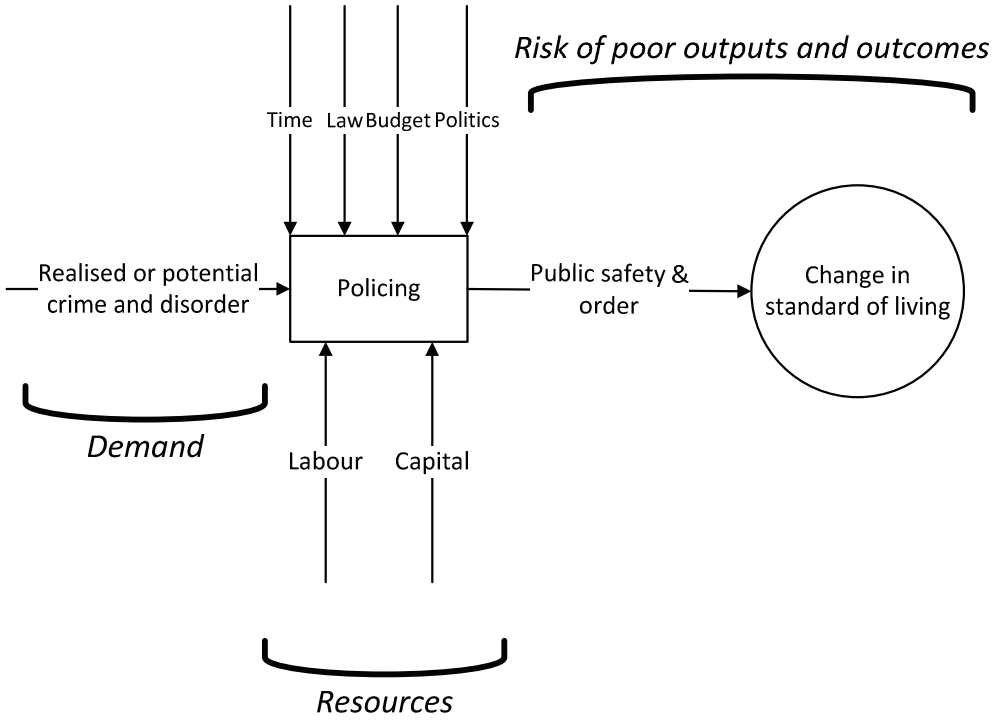


Figure 2.8: RAND Europe FORM framework of policing

Now that we have reviewed the basic elements and the interactions between elements, we can consider a straightforward framing of resilience. In the FORM framework, we can see that resilience is about producing the amount of public safety and order for which the public is willing and able to pay, given the risks and constraints.

Fortunately in good times and bad times these are labour economic questions that all enterprises have to confront sooner or later when their operations are squeezed by the inflexibilities of time and money. Supply-chain managers, for example, face resilience issues every day, which led to 'just-in-time' (JIT) operations. The move to JIT operations was to minimise problems of budget constraints by reducing inventory and storage costs.

For police workforce planning, the real question is: will reductions in human resources increase demand so much that outputs and outcomes will be deemed unacceptable?

2.4 Possible states of resilience

The acceptable level of demand and resources can be different across police forces and therefore the level of resilience can depend on the police force and/or individual police managers. While some police forces may feel they are coping, another police force would argue the opposite based on the same amount of resources and demand.

There is an enormous range of possible states of resilience because each element of resilience (demand, risk and resource) can be defined in a range of different ways.

We can simplify this by assuming there are only two states for each element of resilience, *high* or *low*; this would create six key states of resilience corresponding to the combinations (one state of resilience would be high demand, high resources, high risk; another state

would be low demand, high resources, high risk, and so on). If we alter our assumptions so that there are three possible stages for each variable (adding *moderate)* this would generate 27 distinct states of resilience.

So, even using very simple measures of our three prime variables, we quickly start to generate a complicated array of corresponding resilience states. Faced with escalating complexity, it is important to consider what level of detail is really required to solve the practical problems that police managers face.

2.5 Measurement in the FORM framework of policing

We have described demand and resources qualitatively as either low, moderate or high; however, we have yet to describe the units of measurement. We need indicators representing demand and resources in order to be more clear and concise about what is meant for each state of resilience. In this section, we provide a general explanation of the use of indicators; we then provide particular indicators that can measure demand, resources and risk with associated units of measurement.

2.5.1 General indicator development

Indicators need to be usable, acceptable and easily populated with data

The search for and design of indicators for demand, resources and risk is the creative part of this scientific enterprise. No indicator is absolutely right; it is merely good enough for the tasks asked of it. Often the usefulness of an indicator is enormously increased just because it gains general currency.

For example, the 'cost of living' index is not a particularly subtle or scientific measure, but it does the job and is good enough for use in a wide variety of practical contexts. Part of its success is the availability of appropriate data to calculate the value of the index accurately and consistently over time and place. So an indicator rises in value not only by being usable and acceptable, but by being easily populated with data.

Good indicators have a range of other technical qualities – they bear a constant relationship with the concept measured and are not markedly affected by extraneous factors. That is, fluctuations in value are easily interpreted so that a quantum change at one point in the scale bears a known relationship with the same quantum change at another point in the scale of value. However, the desirability of these technical characteristics increases as an indicator is required to do more and more detailed work – be more reliable and more discriminating between similar states of the concept measured.

2.5.2 Measure of labour resources

A feasible labour resource measure is the number of police officers

In this study, the concern is to consider reducing labour resources; therefore we focus on indicators for labour inputs to deliver policing. One can consider direct and indirect ways for measuring labour inputs; a direct way is one that counts the actual volume of inputs, and an indirect way is one that considers associated costs of inputs (Kimbugwe et al., 2009).

The Office for National Statistics (ONS) suggests the following measures for each type:

- *direct* measure – the number of hours worked by different employees within a sector, accounting for their different skills
- *indirect* measure – the real expenditure for compensation of employees.

No official data on the total number of hours worked by police officers and/or staff are available so we cannot employ the direct measure of hours; however, we can use the direct measure of the number of people employed. The number of police officers and police staff is available at the Home Office website[12] and provided in Home Office reports (Mulchandani and Sigurdsson, 2009). Initially we select the number of officers to represent police resource. This is because the data on police staff cannot be properly matched to the series of police officer data without considerably shortening the series available. Table 2.2 shows the number of police officers in England and Wales from 1994 to 2008.

Table 2: Number of police officers, England and Wales, 1994–2008

Year	Total number of officers
1994	127,897
1995	127,222
1996	126,901
1997	127,158
1998	126,814
1999	126,096
2000	124,170
2001	125,682
2002	129,603
2003	133,366
2004	139,200
2005	141,230
2006	141,381
2007	140,514
2008	140,230

Source: Mulchandani and Sigurdsson (2009).

2.5.3 Measure of demand

A useful measure of demand is the number of recorded crimes

The public demands particular outputs of the policing process. They want public safety and order and look to the police to deliver. The amount of recorded crime is a useful single indicator to represent the supply of policing and the demand for policing.

In order to measure demand, we can draw on existing literature to identify useful and reliable indicators. Gyimah-Brempong and Gyapong (1988) measure the amount of policing delivered with two indicators:

[12] http://www.homeoffice.gov.uk/rds/index.html

- arrest rates of eight different types of crimes (homicide, rape, aggravated assault, robbery, burglary, larceny, motor vehicle theft and arson)
- a non-arrest rate (using an indicator of the population of the city served by a police department).

Diez-Ticio and Mancebon (2002) modelled the production of policing with two main, reactive policing outputs: property offences cleared and violent offences cleared.

The authors argue that the level of production is affected by the seriousness of crimes and differences in capacity to solve them, thus different outputs need to be modelled separately. Lastly, Diez-Ticio and Mancebon (2002) also argue that using the clearance rate, as opposed to arrest rate, better captures the quality of policing because the quality of evidence compiled in each case is independently assessed before a crime is said to be cleared whereas the great majority of arrests are not independently assessed for 'quality'.

Their argument applies to any assessment of quality, effectiveness or efficiency – the output measure selected should capture the characteristics of policing relevant for the study. For example, if the quality of policing being assessed is 'fair administration of justice', then the clear-up rate may need to be supplemented with trial outcome data to develop an indicator that ensures high clear-up rates are not being achieved at the expense of high acquittal rates in the courts.

As with any other enterprise, the supply of output is intended to meet the demand for policing. Therefore, one measure of demand can be the number of recorded crimes, which can also be the measure of output. For England and Wales, there are two data sources for the level of crime: police recorded crime and the British Crime Survey (BCS) (Disley et al., 2009). According to the authors, "[n]either of these sources provides the full picture of crime in England and Wales, and neither gives a better picture than the other" (p. 4).

We recognise there are drawbacks to using recorded crime to represent the true level of demand and supply of policing. Police recorded crime is shaped by factors beyond the actual occurrence of crime, such as legislation, formal recording rules, police recording behaviour, and the reporting behaviour of the public (Maguire, 2007). Equally, the BCS over-represents some crime types and does not represent other types, such as crime against companies, offences of fraud or sexual offences (Disley et al., 2009).

In order to mitigate the risk of misrepresenting the number of crimes, we use recorded crime data from the Research and Development Statistics unit in the Home Office that combine the 'best' aspects of police recorded crime and British Crime Survey data.[13]

For England and Wales, data on recorded crimes has been produced since 1898. Table 3 illustrates recent figures since 2002/03 indicating crime was at its height in 2003/04 and crime levels were lower in 2008/09 than they have been since 2002/03.

[13] For more on this data series, see http://rds.homeoffice.gov.uk/rds/crimeew0809.html

Table 3: Total incidents of recorded crime, UK, 2002/03–2008/09

Year	Total recorded crime
2002/03	5,974,960
2003/04	6,013,759
2004/05	5,637,511
2005/06	5,555,172
2006/07	5,427,558
2007/08	4,951,173
2008/09	4,702,468

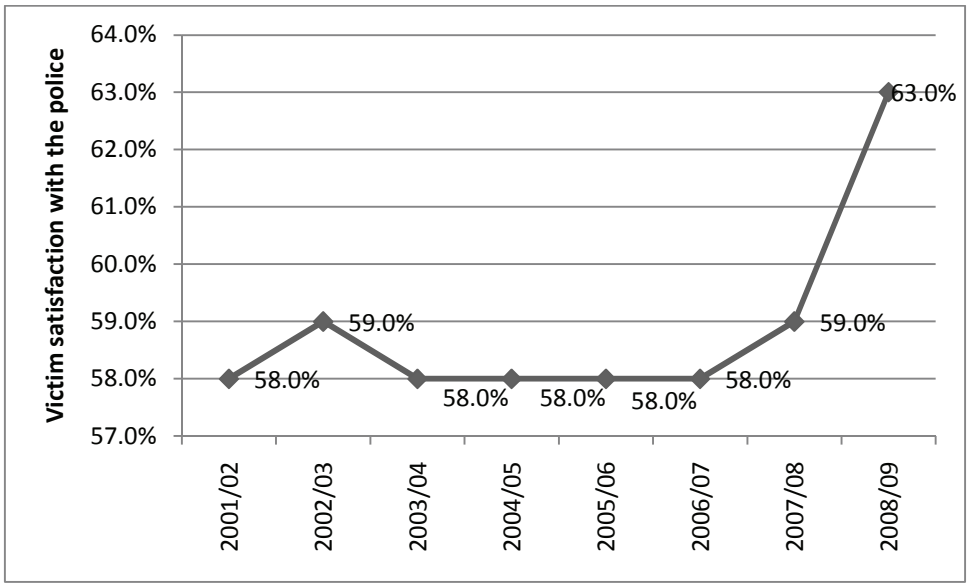
Source: Walker et al. (2009).

2.5.4 **Measure of risk**

No concept of acceptable risk in policing exists

Risk is a probability associated with not delivering a police service as the public desires, for which no measurement currently exists. A potential indicator then could be based on victims' perception of police performance. The public may perceive that the police are wasting money and actually not reducing crimes, or the social cost of crimes, enough. This is arguably a risk of failure to be resilient. In Source: Walker et al. (2009).

Figure 2.9, we plot the most relevant value associated with the public's perception of police performance. It shows the recent statistics on victims' perception of how well the police forces have been doing. In particular, it shows that since 2001/02 the proportion of victims stating they are satisfied/very satisfied has been just under 60 per cent, with a jump up to 63 per cent in 2008/09.

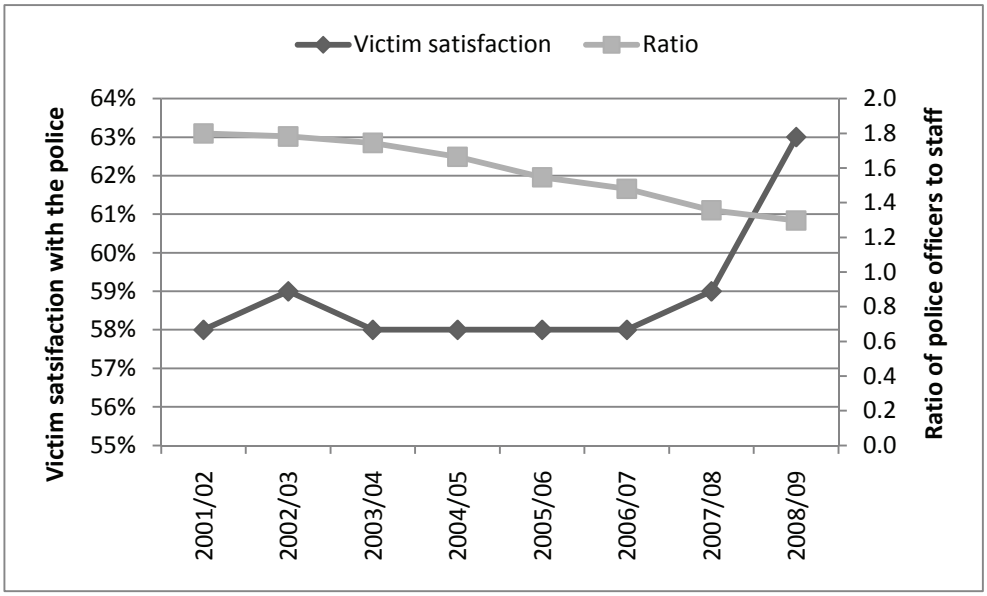


Source: Walker et al. (2009).

Figure 2.9: Proportion of victims stating they are satisfied/very satisfied with police, 2001/02–2008/09

One way in which these data could be useful in this context is to link inputs into policing (police human resources) to outcomes (public satisfaction). As a start, we plotted victims'

satisfaction with police and the police officer–staff ratio[14] over time. If there is an observable correlation, then we can begin discussing how reducing police officers and increasing staff influence outcomes of policing. Figure 2.10 suggests there is no observable relationship between the ratio of police officers to staff and victims' satisfaction with police. That is, decreasing the number of police officers relative to police staff is not associated with changes in victims stating they are fairly/very satisfied with police. This, however, is not evidence of there being *no* relationship; it is only suggestive and requires more in-depth analysis to identify the nature of the true underlying relationship.



Source: Ratio based on Mulchandani and Sigurdsson (2009); satisfaction with police based on Walker et al. (2009).

Figure 2.10: Victim satisfaction and police officer–police staff ratio, 1996/97–2008/09

It would be feasible to include public satisfaction measures in the bundle of outcomes considered in this analysis, especially as the ideal is to measure policing outcomes in a holistic way, but there are, as we have already noted, considerable drawbacks to working with data on public perceptions.

While it is beyond the scope of this report to detail the difficulties involved, the quality of available data on public perceptions of policing is generally poor and not collected in a consistent way across the country. For example, the data above is the only collection of public perception data exclusively focusing on police; however, it is not provided by police force area. The timeframe is also far too short to generate any reliable and valid results.

Moreover perception data is particularly vulnerable to specific media reporting and local and national events. In particular, interpretation of results is complicated by paradoxical effects especially where extraordinary deployment of police resources produces both positive and negative perceptions depending on psychological characteristics of respondents. If perceptions are differentially affected by specific events and reporting

[14] A value greater than 1 means there are more police officers than staff.

regionally and the data are not available by region, this further complicates the use of public perception data in this context.

2.5.5 Valuation of resources

Total expenditure on public safety and order was £31.5 billion in 2007/08

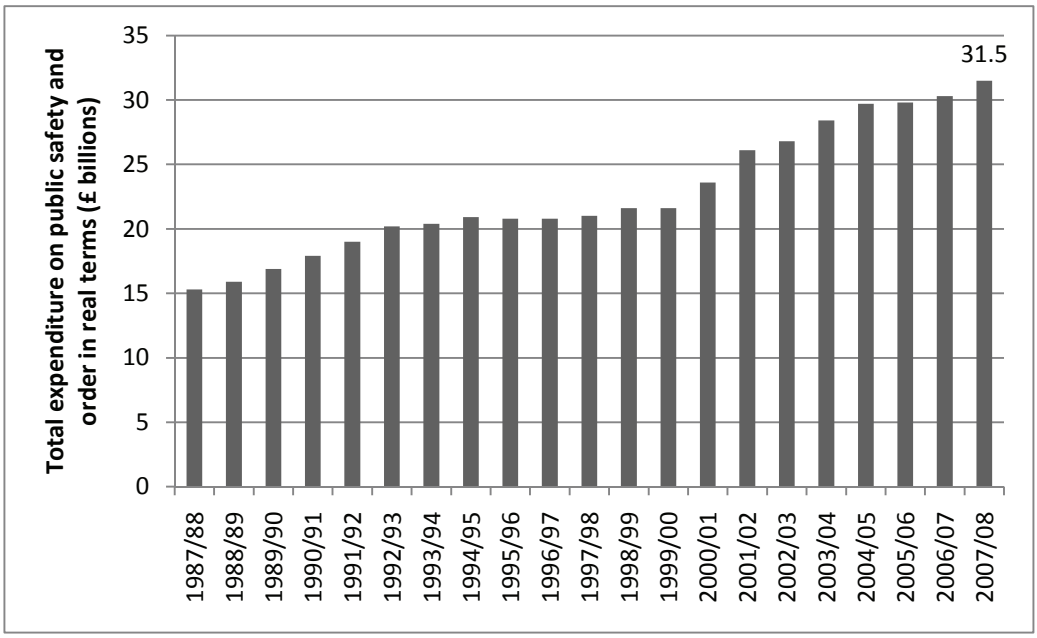
In the private sector, we generally think of a firm generating revenues, which generates its own set of costs. The outcome is profits and firms seek to maximise these profits. In order to develop these measures in the context for policing, we need to assign values to the inputs (labour and capital) and the outputs (policing) in order to identify costs and revenues.

There is general guidance offered by the Chartered Institute of Public Finance and Accountancy Police Force Statistics on how to value the main categories of inputs in policing (Drake and Simper, 2000; 2003). There are three input categories:

- *transport expenses* – transport related expenses, including costs and repairs of police vehicles
- *other capital expenses* – general operating costs such as repair and maintenance, capital financing costs and equipment
- *labour expenses* – employment costs including pension costs of all police officer ranks, traffic wardens, civilian staff and other staff plus the development expenses associated with all these groups (training).

The UK government uses the accounting system for public expenditure known as the Classification of the Function of Government (COFOG), established by the United Nations (UN). This is a system, harmonised among all UN countries, to categorise all government expenditures. The total amount of spending on public order and safety in 2007/08 was £31.5 billion. Despite searching specifically for employment costs, we have been unable to locate this information. Table 2.4 shows the expenditure on public order and safety, 1987/88–2007/08.

Table 4: Total real* expenditure on public order and safety, 1987/88–2007/08



Source: HM Treasury (2008). *Real terms figures are the nominal figures adjusted to 2006/07 price levels using GDP deflators. For years 1987/88 to 2006/07 deflators are calculated from the latest data from the Office for National Statistics (released 28 March 2008). GDP for 2007/08 is consistent with the March 2008 Financial Statement and Budget Report.

It should be the case that using either the direct or indirect measure will return the same results on productivity; however, data availability and precision can make one measure appear greater than another.

2.5.6 **Valuation of demand**

The total social cost of crime more fully captures the potential benefit of policing and was £59.9 billion in 2000

It is relatively straightforward to consider costs associated with inputs; the cost to labour is the wage and the cost to capital is the price of the product. It is, however, more difficult to assign a value to the output – policing – for each crime or potential crime.

One could simply introduce a price associated with each unit of policing equal to the value of input cost;[15] however, this is not very informative.

In order to value the public safety and order the police help to achieve, we start by valuing the financial, physical and psychological costs incurred as a result of crime and add to these any costs directly attributable to crime prevention such as alarm and CCTV systems, guarding etc. Here we can draw on research already conducted for the Home Office. Brand and Price (2000) calculate the social cost of crime[16] for England and Wales in

[15] Policing has been much criticised in Treasury circles for using input costs as a proxy for output values, so the value of policing to a community is said to be equivalent to its total cost. An example of public sector economics moving beyond this simplification is the NHS use of quality of life units of output.

[16] The 'social cost', 'economic cost' and 'economic and social' cost of crime are used interchangeably and include "the costs imposed on individuals, households, businesses or institutions by crimes they suffer directly

199/00 and find the total social cost of crime in England and Wales was £59.9 billion (in 2000). Only half of this cost is due to responding to crime (by the criminal justice system, including Police) and property stolen/damaged (or £30.2 billion). Therefore it is important to consider the other aspects of crime that police attend to.

Data for the UK in 1999/00, see Table 5, illustrate the wide range of costs and incidents by crime types. For example, homicides are vastly more costly than burglaries (nearly 50,000 per cent more expensive); equally, burglaries are far more prevalent than homicides. Note that more recent figures were calculated in 2004/05 by Dubourg et al. (2005); however for internal consistency in this study, we utilise the costs of crime during the beginning of the time-series (1999) of the econometric analysis to follow.

Table 5: Examples of economic and social costs of crime, by crime type, 1999/00

Type of crime	Average cost* (£)	Number of incidents	Total cost (£ billion)
Violence against the person	19,000	880,000	16.7
Homicide	1,100,000	1,500	1.2
Common assault	540	3,200,000	1.7
Sexual offences	19,000	130,000	2.5
Burglary in a dwelling	2,300	1,400,000	3.2
Criminal damage	510	3,000,000	1.5

Source: Brand and Price (2000). *Includes costs for the anticipation of crime, consequence of crime, and response to crime.

Therefore, we consider the value of a unit of policing as the average social cost of crime, where the social costs of crime include the amount spent to avoid a crime (alarm systems), the amount spent on the consequence of crime (e.g. property damage, emotional and physical impact on victims, and lost output) and response to crime (e.g. criminal justice system including police).

2.5.7 Risk preferences of the decision maker

Police and public risk preferences may not match up because of how issues are framed, not because they are actually different

The acceptable measure of risk depends on the risk preferences of the decision maker. Suppose a police manager had the option to choose between a situation in which the cost of crime was guaranteed and a situation in which it was not guaranteed. In the guaranteed situation, the cost of crime is £1.15 million. In the uncertain situation, the cost of crimes will be £1.5 million with 30 per cent probability and £1 million with 70 per cent probability. Although the expected value of each situation is £1.15 million, a police manager may have a preference for one situation over the other. The manager preferring the uncertain situation is referred to as *risk-seeking* (or risk-loving); this type of manager would need a lower guaranteed cost of crime in order to take the guaranteed costs. On the other hand, there may be some police managers preferring the guaranteed £1.15 million to avoid the possibility of generating £1.5 million; these types of managers are *risk-averse*.

(private costs) and wider impacts on society as whole through, for example, responses to perceived risk of crime (external costs)" (Brand and Price, 2000).

Police managers who are indifferent between the guaranteed £1.15 million and the uncertain gamble with an expected value of £1.15 million are *risk-neutral*.

The expected value theory is rooted in a rational model of decision making, and yet individuals make decisions that appear to violate assumptions of a rational model. The observation that actual decisions implied inconsistent preferences led to the work of Daniel Kahneman and Amos Tversky (1979) in which they developed 'prospect theory'.

Prospect theory describes how real-life decisions between alternatives involving risk (alternatives with uncertain outcomes) and those involving known probabilities are made. In particular, Kahneman and Tversky's experiments demonstrate that individuals can be predicted to be risk-averse for gains, or in good conditions, and relatively risk-loving for losses, as when leaders face critical or crisis situations (Kahneman and Tversky, 1979). This is important when considering how the public perceives policing and considering that this perception is now a Public Service Agreement (PSA)[17] target. Put in the simplest possible terms, decision makers facing a crisis and probable losses are more likely to take chances to avoid those losses than they are to take chances to secure increased gains when some gain is in prospect.

In an experiment on individuals' choices, people were asked to imagine they were responsible for a public policy in which a major flu epidemic could take the lives of 600 people. People were split in to two different groups and given policy options as described in the table below.

Group 1	Group 2
Policy A will save 200 people.	Policy A will cause 400 people to die.
Policy B will save 600 people with a probability of 1/3 and save no one with a probability of 2/3.	Policy B will cause no one to die with a probability of 1/3 and cause 600 people to die with a probability of 2/3.

If individuals exhibit consistent preferences then they would prefer the same policy in each group. That is, we would expect the proportion of people in Group 1 choosing policy A to be similar to the proportion choosing policy A in Group 2, since this is the risk-averse option in both groups. However, 72 per cent of people in Group 1 chose policy A, while only 22 per cent of people in Group 2 chose policy A. In other words people are risk-averse for gains and risk-seeking for losses.

We quote these findings to indicate the critical importance of the interaction between how a policy is framed and how it is perceived in risk terms. It may be that the public and police managers agree with each other about what is and what is not an acceptable risk of police failure. However, if police managers frame their policies in terms of making gains, then the public are less likely to put up with a stated risk of failure than if the policy is framed in terms of avoiding losses.

[17] For more details on PSA targets, see http://www.communities.gov.uk/corporate/about/howwework/publicserviceagreements/

2.6 What does RAND Europe's FORM framework deliver?

The framework we have outlined allows us to determine a force's optimal hiring decision – a key question for the NPIA. In part, it will be based on the value of the marginal product.

2.6.1 Optimal hiring decision

As officer earnings increase, so does the pressure to increase the social costs of crime

The optimal point for the number of workers in a labour force is when "the marginal gain from hiring an additional worker equals the cost of that hire" (Borjas, 2005). While we were not originally requested to develop this concept, it has become increasingly clear during this assignment that it would be useful to do so and we therefore include this section for further development in due course. The implication of the hiring rule is that the police service should continue to hire until the marginal social cost of a crime solved or prevented (the gain from the hire) equals the salary and associated costs of the additional police officer. A couple of interesting implications arise from applying the optimal hiring decision to policing:

- If the social cost of crime is low, police officers will be offered relatively lower salaries.
- If the salaries of police officers are held high, there will be pressure to increase the cost of crime.

Positing a pressure to increase the cost of crime may seem strange; who would want to act in this way and how would it be done? However, if we consider the role of media and politicians 'talking up' concern about crime, we can see that real efforts are continually being made to increase the range and intensity of the impacts associated with crime. As impacts increase so will estimates of the cost of criminal events.

The implication for police workforce planning is that if police are seen to have relatively high salaries, they can expect upward pressure on estimates of the cost of crime. This automatically inflates the impact of police failure. For a popular exposition, see Gardner (2008).

The underlying assumption is that the police maximise net benefits by determining the policing output that returns the highest level of net benefit.[18]

To arrive at the optimal hiring decision one needs:

- the amount of policing produced by one additional police officer[19]
- the cost of one additional police officer
- the benefit of policing produced by one additional police officer.

We estimated the relationship between the policing produced by one additional police officer and the number of crimes (for the methodology, see Appendix A). Specifically, we find that on average one additional police officer reduces the number of recorded crimes in one year by 24. If we consider this in hours, one additional police officer is associated with

[18] We assume the police force are price-takers and cannot determine the social cost of crime.

[19] Formally called 'marginal productivity of labour'.

0.013 fewer recorded crimes per hour or 1.3 fewer recorded crimes every 100 hours worked.

Regarding the cost of one additional police officer, we consider the expenditure estimate provided earlier and divide by the number of police officers.

The marginal benefit of a police officer is the change in benefits from an additional officer. We have proposed this value in terms of the social cost of crime; specifically, the change in social costs due to an additional officer changing the number of crimes recorded. The total social cost of crimes in 2000 was £59.9 billion, with 5,170,841 crimes recorded in that year. Therefore, the average social cost was £11,584 in 2000.

Using these figures and the marginal productivity of a police officer,[20] we present in Table 6 calculations on the marginal benefit and cost of an additional police officer, and thus provide the potential net benefit of hiring an additional police officer. The calculations suggest there is currently a net benefit to hiring an additional police officer.

Table 6: Costs and benefits of an additional officer, per annum

	Value (£)
Marginal benefit of an additional officer[21]	278,016
Marginal cost of an officer	224,630
Net benefit of an additional officer	53,386

Source: Authors' calculations.

Both of our benefit and cost measures are based on averages rather than margins (because we do not have information on the marginal social cost of a crime and the marginal expense of an additional police officer). Given both measures are averages, we find costs outweighing the benefits by £53,386.

The police service would want to continue hiring until the £53,386 was reduced to £0 and the marginal benefit equalled the marginal cost. The results suggest there is room for hiring more officers – since the optimal hiring decision is to hire as many workers until the net benefit equals zero, or the marginal benefit equals the marginal cost.

In terms of resilience, if the number of crimes (demand) persists and officers' skills and availability (resources) exist such that the next officer hired can provide a reduction in the number of crimes recorded by 24, then the force might be considered resilient and using risk management successfully by continuing to hire. Equally, a decision to stop recruiting might be plausibly considered reducing resilience. It can be seen that this situation is sustained by the high cost of crime estimate, which is in part fixed by public and political opinion, whereas the marginal cost of the next hiring is concrete and fixed. As we have already noted the law of diminishing returns may not be seen as applying to policing. Another way of stating the same thing is to say that since the cost of crime can always be

[20] See Table A.3 in Appendix A for the results of a modelling exercise to derive this value of the marginal productivity of an officer.

[21] We calculate marginal net benefit as equivalent to the marginal productivity average social cost of crime. We use the value from our modelling exercise, which finds the marginal productivity of 24 crimes recorded per annum and the average social cost of crime calculated as £11,584 per annum.

talked up and the amount of crime to be prevented is infinite, there will always be a net benefit associated with extra hiring.

2.6.2 **Estimating the states of resilience**

When reducing human resources, there are three key states of resilience to consider

The FORM framework focuses attention on the variables we need to consider in identifying key states of resilience. We can examine different levels of demand and how those different levels of demand relate to levels of resource. This answers a question such as: how many resources were used to meet a given level of demand? (see Figure 2.11).

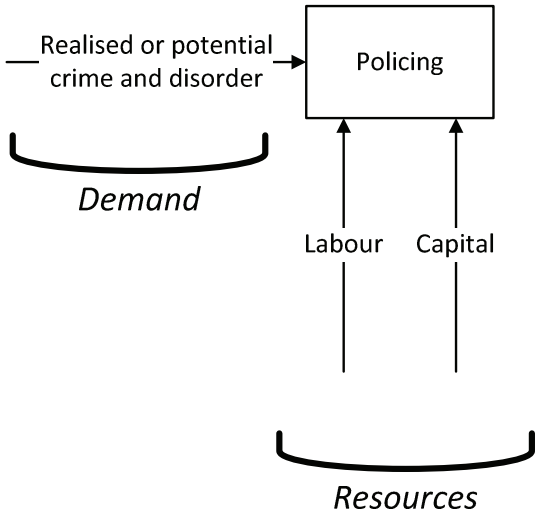


Figure 2.11: Area of the FORM framework implicated by the 'Resilience Hypothesis'

The main focus of this study is estimating the minimum level of officers to address demand. We therefore need to understand how a change in the number of officers influences the level of demand. We approach this question by considering two extremes – low resources and low demand – and the corresponding levels of demand and resources, respectively.

We then turn to the issue of identifying some median point between the two extremes – moderate levels of resources and demand. Moderate resilience we define as the point where demand and resources stabilise to their natural, long-run levels. With no acceptable measure of risk, we discuss whether each state would be associated with low or high levels of risk. We allow the risk levels to emerge from the levels of demand and levels of resources. We thus avoid the floating definition of risk that has bedevilled previous attempts to define and investigate resilience.

Therefore, the important resilience states we consider are:

- *low levels of resources and the corresponding level of demand* – this would tell us how much demand goes up as we reduce resources; we call this state of resilience 'minimum resilience', since it corresponds to the minimum level of human resources (the issue of interest in this study)
- *low levels of demand and the corresponding level of resources* – this would tell us the minimum amount of resources we need to keep down the demand; we call this

state of resilience 'maximum resilience', since it corresponds to the maximum level of human resources necessary

- *moderate levels of demand and resources* – this would tell us the minimum amount of resources we can expect in the long run that stabilises the relationship with demand; we call this state of resilience 'steady-state resilience', since it corresponds to the long-run level of human resources we can expect.

In the next chapter, we go a step further and estimate values for demand and resources in each of these states by identifying an appropriate and well-developed statistical model.

CHAPTER 3

Quantification of three states of resilience in the FORM Framework

Thus far, we have prepared the conceptual framework to describe how demand, resources and risk factor into workforce decisions. This should lead to a better understanding of what influences the ability of police to meet changes in demand. We now quantify the level and mix of human resources – in particular, police officers and staff – associated with different levels of demand (proxy variable: recorded crime).

In this chapter, we present our empirical strategy and the data used to implement it. We explain what our estimates can show and present the results of our estimations. Finally, we provide a practical discussion of what the results mean for police managers and policy makers.

3.1 Empirical strategy and data specification

3.1.1 Empirical strategy

The empirical strategy aims to identify officer levels associated with a range of demand

As we have already explained, there can be many combinations of demand and resources and thus states of resilience. It is important to focus on those combinations that provide the most information and are most useful in achieving the objectives of the study. The most pressing policy issue currently facing the police service is potential reductions in resources. Our primary objective therefore should be to understand what may happen to demand and thus resilience if and when police numbers are reduced.

So, our strategy is to examine two extreme levels and the long-run, stable level of resilience (the median point). The two extremes are a 'maximum' state of resilience with no crime to create any demand for policing and a 'minimum' state of resilience with no police officers (see Table 7 for a summary of each state of resilience). We arrive at estimates of these theoretical extremes and the moderate state by reference to a particular biological model, which – having reviewed the available evidence – appears to be analogous. We use available data to test the appropriateness of the model.

Once we have estimated these three basic levels of resilience, police workforce planners will have a tool to hand which will allow them to assess where on the scale of resilience the current situation lies and the level of resilience implied by any particular reduction in police numbers or rise in crime.

Table 7: Demand and resources facing the police service, by resilience state

	Demand	Resources
Steady-state resilience	Moderate	Moderate
Minimum resilience	High	Low
Maximum resilience	Low	High

We have not yet discussed risk, logically an important element of resilience and therefore of the FORM framework. As described in our development of the FORM framework, risk, as we define it for the context of policing resilience, is the probability that policing services are not delivered in a timely, appropriate and sustainable manner. We have already explained that as yet policing management decisions are not made on the basis of an overt statement of acceptable risk of failure. While some policing targets such as response time to 999 calls imply an acceptable risk of failure and there are considerable data available on actual levels of failure, these data have never been translated into formal management decision-making metrics. This makes it impossible to include risk in this quantitative assessment. We can only, therefore, examine resources and demand and provide police workforce planners with a framework for incorporating risk in the future.

To estimate the moderate state of resilience, the FORM framework is best captured in the biological predator–prey model where police 'prey' on crime

If the relationship between police numbers and crime is unique in character then producing a model that describes all states of the relationship would be a long and arduous task involving the collection and analysis of copious amounts of data. However, there are a huge number of existing models which describe the dynamic interaction of different populations. By using the FORM framework as a guide to the real nature of the populations and the form of their interaction in this case, it may be apparent that a sufficiently analogous situation has already been modelled elsewhere. If this turns out to be the case, we can adopt that model and use it as a tool to estimate what we need to know even though we lack sufficient data on policing to construct a 'tailor made' model. The FORM framework describes a situation in which the existence and size of the population of police is dynamically related to the size and trends in the crime population. As crime rises so police resources are increased to deal with the threat. As crime levels shrink, so this affects police workforce levels. A set of extraneous (contextual) factors also have an effect on the way the relationship works out in practice.

A theoretical model that captures this general type of relationship is described in the biological scientific literature and is known as the predator–prey model. In biology, dynamical systems are used to describe the population evolution of a predator and its prey (Berryman, 1992; Kramer and Drake, 2010; Peng et al., 2010). Estimating this theoretical model provides answers, for example, to questions regarding whether a species is endangered or whether a long run equilibrium or steady state of the predator population and prey population is likely to exist.

This theory can be elegantly adapted to crime and police: police forces represent the predator that 'needs' crime to 'survive and thrive'; on the other hand, crime is the prey that, if not 'threatened' by police, will continue to proliferate. Predators and prey

populations are also affected by aspects of their environment just as police and crime are affected by extraneous variables.

The predator–prey model has been used before to understand criminological relationships; one study presented the theoretical foundations of the relationship between muggers (the predator) and muggees (Neher, 1978). The author argues that muggers and muggees have a similar relationship to fisherman and fish and over-mugging can occur in the same way as over-fishing. The model could equally be applied to burglars and householders, the effect of crime prevention investment and the slow shift away from burglary to other forms of acquisitive crime.

The predator–prey model is ideal for estimating both extreme states of resilience and our defined median point of moderate resilience between the two extremes of high and low resilience.

In estimating the predator–prey model, we provide figures on three potential policing strategies

Having established that in theory the behaviour of predators and their prey is a useful proxy for the way crime and policing interact, the next stage is to estimate the theoretical model with real data on demand for policing (crime) and police resources. This is meaningful because we have enough real data to show that there is a dynamic, linear relationship between resources and crime. Therefore, even if the state of resilience involved has never been properly observed for the UK as a whole, the model of the relationship can yield the numbers we need.

To estimate the predator–prey model we need to understand properties of the data (we provide more detail on data in the next section). This helps to identify the estimation technique that will provide the most reliable and consistent results. We can then use the technique three times to calculate the three basic states of resilience.

Reaching an understanding of the properties of the data is achieved by going through a series of empirical tests. We start by using statistical methods which require the data to conform to strict rules. We then move on to tests with fewer such underlying requirements on the grounds that the data we are working with may indeed not conform to the strict rules associated with the first test. We refer to this as relaxing the assumptions. If we find that the second test calls into question the results of the first, then we adopt the 'safe' procedure of rejecting the preliminary results. This approach protects us from the error of accepting a finding as true when it is not (see Box 3.1 for further details on the assumptions and process).

In summary, we applied the most systematic and robust approach available within the constraints of the study. Table 8 summarises the key aspects of our empirical strategy.

Table 8: Summary of the empirical strategy of the predator–prey model

What kind of model is it?	Theoretically: the relationship between predators and their prey. Empirically: Ordinary Least Squares (OLS), autoregressive distributed lag, cointegration.
What is the aim of the model?	To determine the demand and resources within a minimum, maximum and steady-state level of resilience.

Why did we choose the model?	It is theoretically consistent with experts' explanation of the relationship between crime and police level. It is empirically consistent and unbiased over time.
What does the model test?	The level of crime and police officers below or above which police forces are not resilient.
What can it tell us about policing?	Strategies to achieve stability between the number of police officers and crime. Implications of changing acceptable risk levels.

3.1.2 **Data and measurement**

Development of the FORM framework provides useful and reliable measures for estimation

As described in the FORM framework, useful and reliable measures of levels of demand and resources are recorded crime and police force numbers, respectively. There are a wide range of other measures that could be used, including complex indices and proxy variables; however, for the purposes of this preliminary and ground-breaking study, we use the most obvious and accessible of the options. In this section, we describe the measures and data we use.

Box 3.1: Assumptions and procedure for taking into account uncertainty

1. We first start with the assumption that the police workforce levels this year are only associated with the crime levels of this year. For our theoretical model, the technique applied for this assumption is called an Ordinary Least Squares (OLS) estimation and is standard for producing estimates of the short-run relationship between factors.
2. Next, we relax the assumption that police and crime are only contemporaneously correlated – it may be that the level of crime, say, three to five years ago determines current levels of resource. The technique is called an autoregressive distributed lag (ADL) regression.
3. A key underlying assumption so far has been that where we observe police force levels and crime levels moving together, changes in one variable will directly lead to changes in the other. This may be a relatively risky assumption, so we relax the assumption and acknowledge that other factors may account for the apparent relationship between police officer and crime levels. This technique is known as cointegration analysis.

For a more formal description of each technique, see Appendix B.

Recorded crime data is an available and useful proxy measure for demand

For the number of crimes recorded, we use aggregate data that combine the following types of crime into one 'variable' for crime: violence against the person, sexual offences, robbery,

burglary, offences against vehicles, other theft offences, fraud and forgery, criminal damage, drug offences and other offences.

The data set we utilise for information about crime levels is provided in Walker et al. (2009) and covers the period 1994–2008 for England and Wales. It is the most reliable and complete data set for crimes recorded across England and Wales (the area for which the NPIA is responsible) over a long enough period of time to conduct analysis.

The number of officers is the most readily available and useful measure of human resources

For the number of police officers we use aggregate data of police force strength. We include the following ranks of police officers: ACPO ranks, superintendents, chief inspectors, inspectors, sergeants, constables and secondments.

The data set we utilise for information about police officer and staff levels is provided in Mulchandani and Sigurdsson (2009) and covers the period 1994–2008 for England and Wales. It is the most reliable data on the number of officers and staff across England and Wales police force areas.

Statistics suggest police officer levels have increased while crime levels have remained stable

Table 9 gives a simple statistical description of the variables used in the formal empirical model. The mean number of police officers is 131,830, which has varied over the period 1994–2008 from approximately 124,000 to over 140,000. The mean number of recorded crimes is nearly 5.3 million.

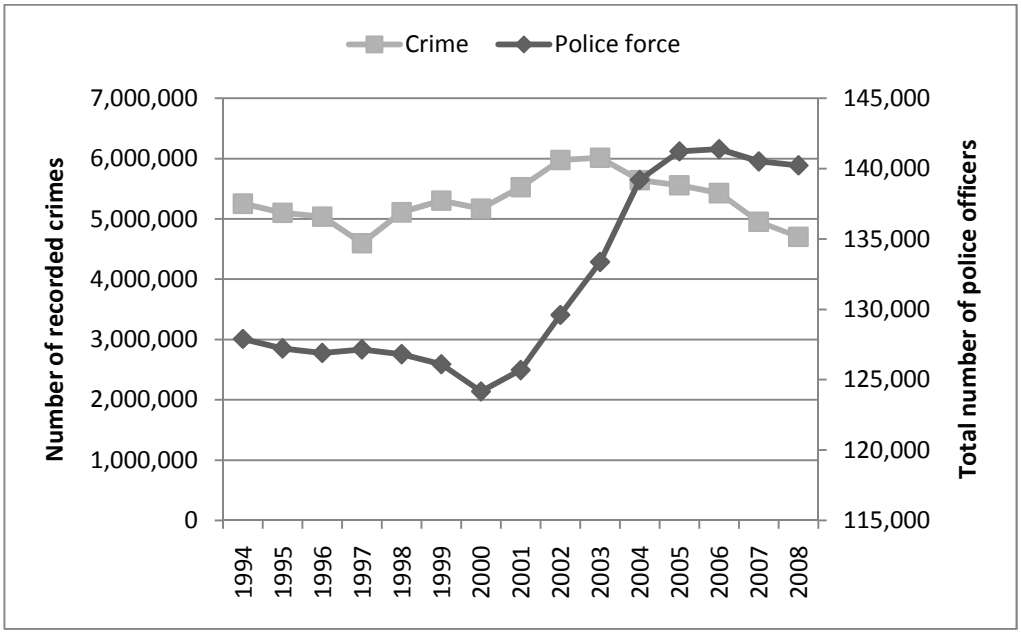
Table 9: Summary statistics, 1994–2008

	Mean	Std dev.	Min.	Max.
Total police officers	131,831	6,679.0	124,170	141,381
Crime[22]	5,290,752	409,539.2	4,598,357	6,013,759

Source: Authors' calculations based on Walker et al. (2009) and Mulchandani and Sigurdsson (2009)..

In order to demonstrate how the levels of crime and police officers have varied over time, we illustrate in Figure 3.1 the levels of each from 1994 to 2008. The figure shows levels of crime have been relatively stable, while there was a large increase in the number of police officers over the period 2001–2005.

[22] The way in which crime is recorded changed in 1998; as a consequence the mean is an under estimation.



Source: Walker et al. (2009) and Mulchandani and Sigurdsson (2009).

Figure 3.1: Trend in number of crimes and police force levels, 1994–2008

At a first glance, it seems crime and police are not correlated because they do not obviously move together in any observable way; however, proper modelling and robust techniques of estimation reveals otherwise.

3.2 Results

3.2.1 Steady-state level of resilience

Crime and police officer numbers are stable at approximately 5 million crimes and 130,500 officers

The predator–prey model sets out to predict when and if the two populations reach a steady accommodation where, all things being equal, there will be no further major changes in the number of predators (police officers) or prey (crimes).

Using the dynamic OLS cointegration technique, we find that crime stabilises to a long run level of 5,123,854 crimes and 130,560 police officers per annum (Table 3.4).[23] Comparing these figures with those for the latest year for which we have data, 2008, they represent a 7 per cent reduction in the number of police officers and a 9 per cent increase in the number of recorded crimes.

Table 10: Summary of demand and resource levels, steady-state resilience, based on 1994–2008 figures

Level of resilience	Demand*	Resources**
Steady-state resilience	5,123,854 crimes	130,560 officers

*Number of recorded crimes. **Number of police officers.

[23] These are under-estimates since the crime record method changed in 1998.

The important implication of this finding is that going forward from the last data point (2009), the number of crimes and police workforce levels is dynamically heading towards this level of steady state accommodation (of approximately 130,500 police officers). However, an extra level of resilience is currently 'built in' to the system (the extra 7 per cent of police officers).

In a dynamic world, what is satisfactory as of 2009 will need to change over time to remain satisfactory. These results will assist police managers who find the resilience strategy satisfactory, as of 2009, and would like to maintain it.

To illustrate the dynamic process by which the police workforce and crime levels could change over time to arrive at their steady state level, we present Figure 3.2 below. The figure illustrates how the police officers (predators) work to reduce crime (the prey). However, when there are more police officers than necessary and crime is 'too' low for the 'predator' population, there are a number of important implications arising from the model.

First, it may be that fewer police officers work directly on reducing crime and correspondingly more will work on ancillary tasks. From a macro labour economics point of view, it may be that because the 'supply of workers' is rather high, the remuneration that would be offered is potentially lower than might be offered for other types of jobs. The expected knock-on effect of this should be observable in a high rate of labour turnover or difficulties in recruiting. Finally, the size of the predator population can be reduced to an optimum by absenteeism and/or low productivity. Any combination or permutation of these compensatory mechanisms may be observable in real life.

On the other hand, when the number of police officers is too low, crime flourishes and it can take up to three years for police managers to acquire the necessary police officers to reduce crime. Again, from an economic point of view, it may take time to put together the economic incentives to recruit the extra officers (or to reduce the flow of those leaving the profession). It may also take time to acquire the funding for those incentives and to train individuals to operate effectively as police personnel after they have been recruited.

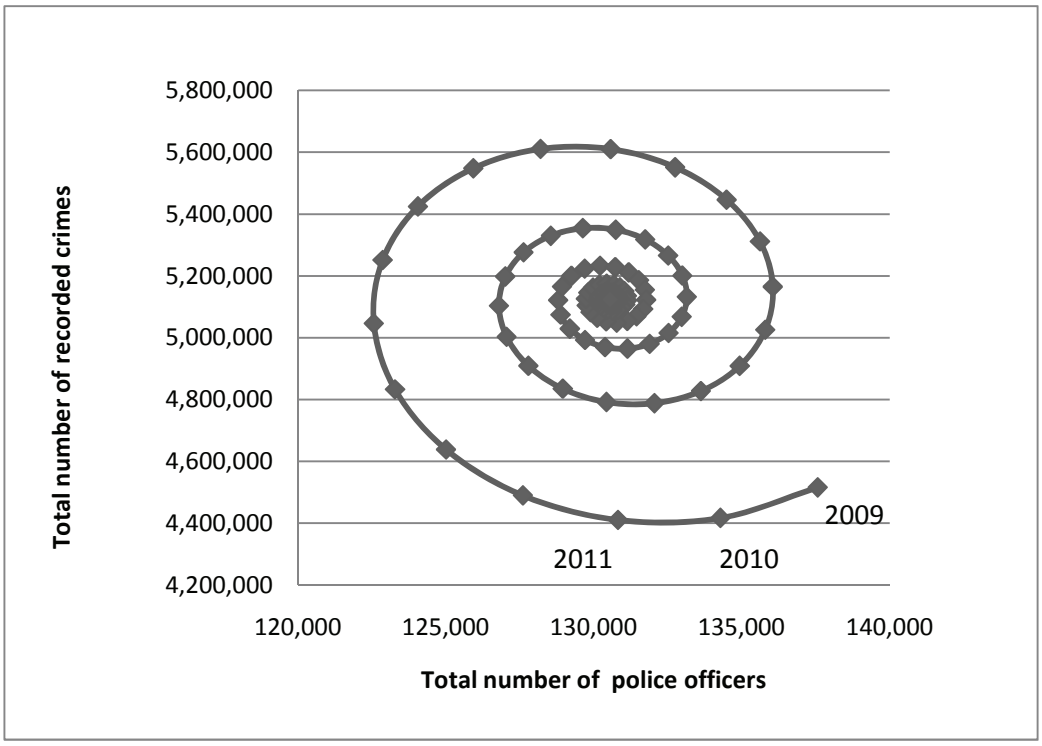


Figure 3.2: Police force and crime level dynamics

3.2.2 Minimum level of resilience

Minimum resilience means zero officers and over 26 million crimes by 2020

We also attempt to identify the extreme situation in which there are no police officers – where the 'predators' no longer exist and the 'prey' population expands. We set resources to zero and use the dynamic OLS cointegration technique to identify the corresponding level of demand (Table 3.5). Our results in this extreme case show what would be the growth rate of crime over time if a strategy were employed to systematically remove police officers from England and Wales.

The results confirm how important police officers are to reduce recorded crime. Specifically, without the presence of police officers, crime could rise approximately 70 per cent[24] in the first year and stabilise to a 3 per cent annual rate of change in the long run (e.g. beyond 2020). This minimum level of resilience shows the theoretical 'worst case scenario' to managers who either wish to reduce the current resource levels or are under pressure to do so. It provides an important benchmark in combination with the other basic states of resilience.

Table 11: Summary of demand and resource levels, minimum resilience

Level of resilience	Demand*	Resources**
Minimum resilience	7,955,512 increasing to 26,722,754 (by 2020)	0

*Number of recorded crimes. **Number of police officers.

[24] This is an under-estimate since crime record method change in 1998.

We illustrate in Figure 3.3 the process by which we move from the current situation to this minimum level of resilience: there is a rapid and large growth in the rate of recorded crime, which slows and stabilises over approximately ten years. Although there is a large increase at first, the rate of increase does subside. After the first six years, the growth rate of crime would be approximately 8 per cent, stabilising to approximately 3 per cent each year after 2020. Note that these are the annual rates of change; the actual levels of recorded crime would still increase year on year. The graph is presented to demonstrate how, even with no resources, rates of increase tend to slow and stabilise and most of the catastrophic effect of massive resource reduction would be felt very quickly.

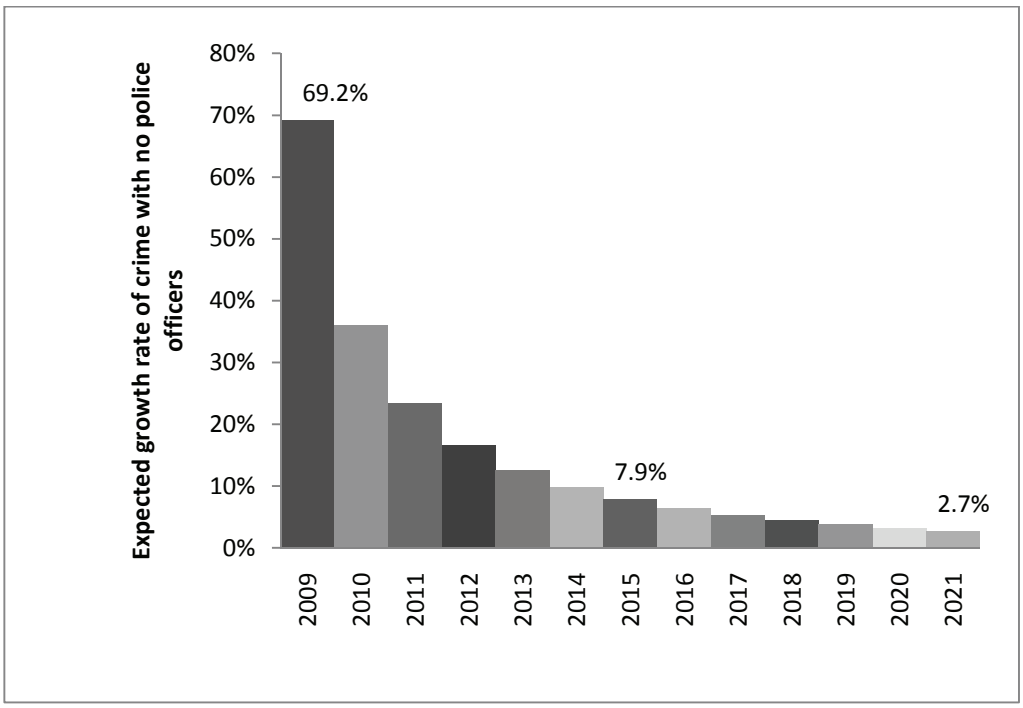


Figure 3.3: Expected crime growth rate (assuming no police officer presence)

3.2.3 Maximum level of resilience

Defeating crime completely would take significant increases in resources

We also look to identify the extreme situation in which there is no crime. We estimate the predator–prey model when the 'prey' (crime) is set at zero and run the dynamic OLS cointegration technique to see what happens to the number of 'predators' (police officers).

We identify the optimal police workforce level necessary to defeat crime in a given period; Table 3.6 shows the long-run, minimum level is approximately 156,000. In this situation, there are so many resources addressing crime levels that crime cannot thrive and the demand for policing services has been completely addressed.[25]

[25] Saturation policing at special events can approximate absolute high resilience.

Table 12: Summary of demand and resource levels, maximum resilience

Level of resilience	Demand*	Resources**
Maximum resilience	0	324,523 declining to 155,616

*Number of recorded crimes. **Number of police officers.

Results of this maximum level of resilience estimation demonstrate to managers, who may feel they are taking on too much risk with their present strategy, the quantitative workforce implications of changing their approach to a theoretical strategy of defeating crime altogether. Figure 3.4 extrapolates from available data and shows how many police officers would be needed theoretically to defeat crime one year from now, two years from now, and so on until 145 years in the future when the police officer numbers required to do the job finally stabilise. The figure shows that if the police service of England and Wales wanted to completely eliminate crime next year, it would need to acquire 324,523 officers. The officer numbers fall each additional year the police force is willing to wait to eliminate crime. Beyond 145 years from now, however, the number of officers to defeat crime is the same each year – 155,616 police officers. In other words, if the police force consisted of approximately 155,000 police officers, it would take 145 years to eliminate recorded crime.

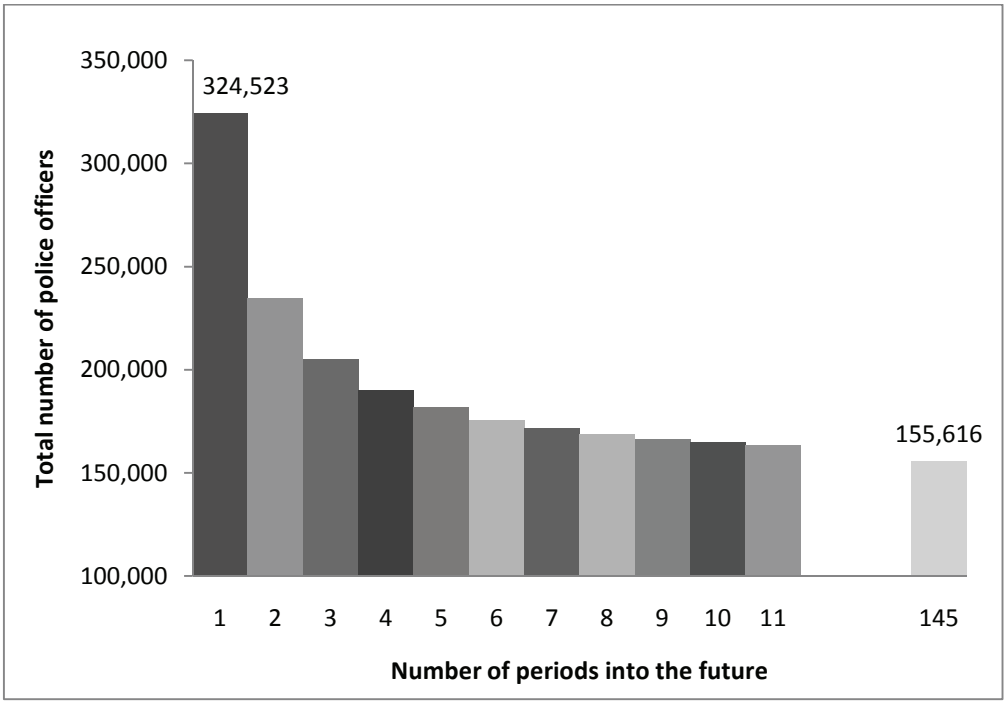


Figure 3.4: The minimum level of police officers necessary to defeat crime

These extreme case estimates are useful as a benchmark against which to assess realistic strategies for crime reduction with different levels of resource. To illustrate how we can develop this approach we perform more in-depth analysis in which we consider the financial implications of three indicative hypothetical strategies based on the above:

1. defeat crime in year 1 and in year 2
2. defeat crime by year 2

3. no police in the starting year and increase officers to defeat crime in year 2: juxtapose the two extremes).

Results suggest this last strategy dominates both the others. The real-life implication of this finding is that it is more effective to severely reduce the number of police officers, even if crime increases, and to save and invest the money for future recruitment. To achieve a return to the level of crime before the severe reduction will cost less than the accumulated savings. This is possible because:

- the rate at which savings accumulate is greater than the rate at which crime increases
- the total amount of money saved is more than the amount that would need to be spent to retrieve the original crime level.

From a practical point of view, it is clearly not possible to have no officers and the outputs from the modelling do not take into account any political and social pressures. However, it does provide a framework for thinking about potential strategies and their outcomes. Moreover the modelling based predictions are counter-intuitive and contradict much accepted policing wisdom. For this reason alone further testing and elaboration will clearly be necessary but might well repay the investment.

CHAPTER 4 Conclusions and discussions

This study aims to provide police workforce planners with qualitative and quantitative tools for managing demand, resources and risk in policing.

We develop a qualitative tool – the FORM framework – by systematically defining the problem of resilience and describing elements of resilience and their interactions. The framework allows us to identify an appropriate theoretical model – the predator–prey model – of the relationship between demand and resources in policing.

We apply the most robust technique to the predator–prey model to quantify three states of resilience that may be particularly interesting for police workforce planners faced with pressure to reduce the number of police officers. To help workforce planners think about the economic implications of particular strategies, we test three hypothetical strategies for completely eliminating demand, and implicitly radically reducing police managers' position on risk.

Constructing RAND Europe's FORM framework helps identify the main problem with the current discussion of resilience in policing circles. The internal police debate on resilience has prompted an essentially subjective and fluid definition of demand and resources. Moreover, the relationship between demand and resource has been permitted to vary through a range of unstated assumptions about the acceptable risk of failure. To make progress, resource and demand must be objectively defined and if risk is to enter the equation, the acceptable risk of failure must be clearly stated either overall or for particular operations. We offer the FORM framework as a means of specifying and disentangling the elements of resilience so that police workforce planners can better manage the resilience debate in future.

Establishing a theoretical stable state of resilience which entails a 7 per cent reduction in police officer numbers and a 9 per cent rise in crime levels (as compared to 2009 levels) provides a direct challenge to traditional thinking on police numbers. Tests of strategies to defeat crime strongly imply that an initial rapid reduction of resources is preferable to slow reductions. In the current fiscal situation this important counter-intuitive finding urgently needs further testing and discussion.

4.1 Limitations

The results of this study are presented with some caveats, mostly related to gaps in data. The following data gaps were identified.

More precise estimates could have been obtained with data on the number of police officers and staff across police force areas over time

Police officer and staff numbers were available either over time for England and Wales, or across police force areas at a single point in time. More precise estimates require long-run time series of data for each police force.

The scope of the analysis was narrowed because there are limited data on the number of people in each policing position or class of position

Certain classes of human resource in policing may have a disproportionate effect on resilience when crime demand is of a certain type. The data to test this proposition and apply the predator–prey model are currently unavailable.

Data are needed on the total number of hours actually worked by officers and average number of hours per officer

These data would have improved our estimates by using what is considered to be a more precise indicator of labour effort. Furthermore, we could demonstrate resilience at a more individual level, rather than the aggregate 'total number of officers'.

Data on overtime over-spend and under-spend would be a useful proxy for resilience; this could be supplemented by data on the use of mutual aid and volunteers

The Home Office Police Productivity Unit has investigated the system used by forces to control overtime over-spend; however, this study was based on managers' reports and did not involve data on actual overtime over-spend and under-spend by forces. This data is not published or available centrally Overtime over-spend and under-spend would be an extremely useful variable on which to collect comprehensive data because it would add another perspective on resilience. Adding real overtime levels to departmental human resource figures would provide better estimates of real resources deployed. We assume that the data are available at force level because overtime payments have to be accounted for at all levels in each force. Serious concern about resilience would lead inevitably to aggregating these data as a means of improving the analysis we have performed above. To round out the resource/demand picture, especially in exceptional operational circumstances, overtime data would need to be supplemented with mutual aid and volunteer deployment data. Volunteers would include police staff providing services beyond their contracted responsibilities. These data are not available centrally.

4.2 Suggestions for further research

Linking outputs and outcomes is one area of the FORM framework that is poorly researched

Demand can be measured in a number of ways, e.g. calls for service, and victimisation rates as measured by the BCS. Various measures could be combined into a weighted index to give a rounded measure that more satisfactorily factored in proactive policing effort.

It is important to recognise that constructing optimum outcome measures for effective workforce planning is an entirely different enterprise from constructing targets against which to judge police officer and staff (resource) performance. We would hope that once this is fully recognised, it will be much easier to experiment with different measures and obtain a wider range of relevant data from police forces.

Identifying the public's risk preferences would help police managers and policy makers communicate their strategies

If the NPIA is to truly understand the preferences of the public, it is worth exploring how we might acquire such information. One method would be to conduct experiments in which individuals choose the policy they would adopt if they were police managers. Such experiments allow us to compare how different groups balance risk of failure and cost. It is important to establish whether policy makers, managers and the public place the point of balance in the same or radically different places. Such experiments can also be used to arrive at an accommodation between positions. If police managers are aware of how the public see risk associated with police failure, they may be better able to frame their strategies so as to garner public support for them.

Identifying the extent to which the public is willing to pay for policing would help police managers and policy makers develop their strategies

There is a potential discrepancy between the level of risk the public is willing to pay for and the amount of risk a police manager is willing to accept for a given amount of funding. In order to tackle this issue and understand how much the public values different situations, a willingness-to-pay experiment would ask individuals to choose between different situations, each of which has a different cost or price. This value would help police managers and policy makers understand how much the public values different types of policing and to be more effective and efficient in deploying their resources. This approach has already been successfully used by RAND Europe to investigate public willingness to trade privacy for increased security in a counter-terrorism context. It should be emphasised that such experiments are extremely cost-effective when compared with more popular attitude surveys.

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APPENDICES

APPENDIX A: An in-depth discussion of production and productivity issues in policing

In this appendix, we formalise the economic issues of policing production and labour productivity. We start by considering previous literature on this subject and present a formal model of policing production. We then discuss how labour fits into production and the interaction between workers. Lastly, we formalise the issue of demand shocks. By examining these issues with a more formal structure, we are able to develop the implication of reducing some workers (e.g. police officers) and increasing other workers (e.g. police staff).

A.1 Policing production function

We have identified three categories of literature utilising policing production functions (see Table A.1). They are generally: testing the economics of crime, estimating production and cost functions, and evaluating efficiency. Each has a different overall research aim and Table A.1 shows the breadth of research involved in considering a policing production function.

Table A.1: Summary of literature investigating policing production functions

Reason for policing production function	Literature
Testing the postulates of the economics of crime through simultaneous equation models, which include an equation of the police production function	Ehrlich (1975), Carr-Hill and Stern (1979), Burrows et al. (1982), Craig (1987)
Estimating the production or cost function assuming different functional forms	Phillips (1978), Cameron (1989), Gyimah-Brempong (1987), Gyimah-Brempong and Gyapong (1988), Gyimah-Brempong (1989)
Evaluating efficiency by way of nonparametric techniques	Parks (2005), Levitt and Joyce (1987), Thanassoulis (1995), Carrington et al. (1997)

Source: Diez-Ticio and Mancebon (2002).

In a more formal representation of policing production, we start by considering both aspects of policing – responsive and preventive – in one framework. This means considering all police activities as the production of 'policing', which we label as Q. To produce Q, police forces need workers (L), such as police officers and staff, and capital (K), such as cars, equipment and other physical inputs. Therefore, a simplistic production function is:

$$q = f(L, K),$$

where $f(L, K)$ specifies how much policing can be delivered for any combination of labour and capital.

Figure A.1 demonstrates the relationship between the number of workers and delivery of policing, holding capital fixed. All the points along the 'Total product' curve show more police allows for more policing. There is a limit, however, to how much policing can be delivered and the 'Total product' curve begins to level off; eventually there is simply nothing more that can be offered.

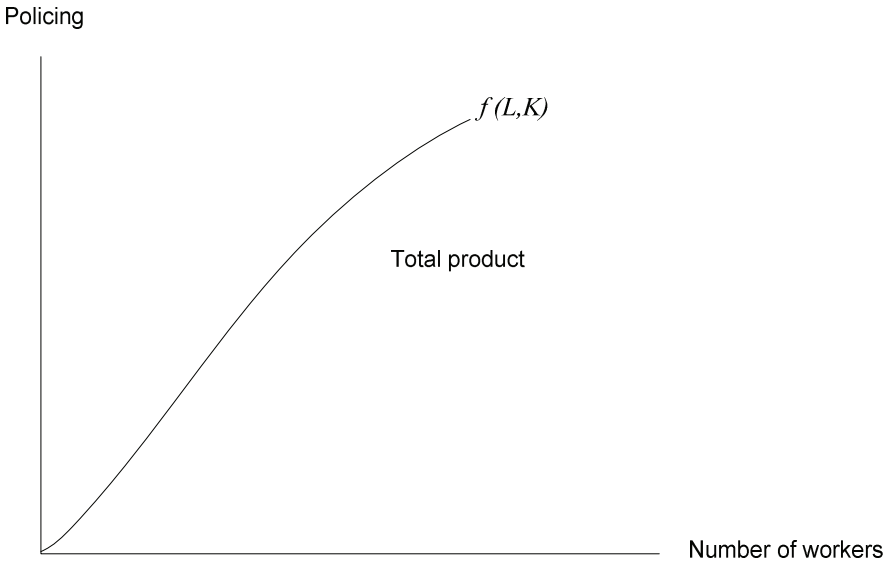

Figure A.1: Representation of policing production

A.2 Productivity

In this section, we consider how to identify the implications of additional resources and of the interaction of resources.

A.2.1 Complements and substitutes in production

It may be more beneficial for policing production to reduce some kinds of 'workers' (e.g. police officers) rather than others (e.g. police staff). This can happen, for example, if overall resources are limited and the police force considers reducing the number of police officers relative to police staff in order to reduce costs (on the assumption that staff salaries and associated costs are on average lower than officer salaries and associated costs).

The idea of reducing more workers of one type than other, and still maintaining production, implies workers are complements to each other (and improve each other's productivity). As a practical example in policing, it may be that traffic patrol officers and traffic wardens have different skills but improve each other's ability to reduce the number of auto crimes and traffic offences. Traffic wardens by their presence on the streets and their ability to issue fixed penalty notices reduce the total number of relatively trivial

offences that traffic patrol officers have to attend to. This allows the patrols to concentrate on more serious offences that might go undetected if their time was otherwise taken up with large numbers of trivial matters. In essence, it is not only the number of workers, but the interaction of types of human resource that can affect productivity. To understand if two types of workers are complements or substitutes, Seidman (1989, p. 1) explains that "two factors are complements if an increase in one factor, holding all others fixed, raises the marginal product of the second". For the police, this means if the police forces need to be reduced, then it will be more efficient to reduce those workers that have less positive (or negative) effect on the productivity of others.

One Spanish study examined the relationship between the ratio for police officers to staff and two types of crimes cleared – violent and property crimes (Diez-Ticio and Mancebon, 2002). The findings from this study were that there is a weak but statistically significant relationship for the clearance of violent offences, but not for property clearances. This suggests having a higher ratio of police officers to staff improves policing of violent crimes, but has no effect in relation to property crimes.[26]

A.2.2 Average output per worker

The importance of introducing the production function is that we now have a framework for discussing productivity in policing and how a change in the number of workers affects output. This is often what is thought of and reported in documents as labour productivity; for example, in writing for the ONS on labour productivity in the public sector, Kimbugwe et al. (2009) note that "[p]roductivity is often expressed in terms of labour (labour productivity), frequently defined as output per person employed".

Now, let us consider a generic entity that delivers a service, where the delivery of the service is called the 'output' of the entity, through the effort of their employees or workers. We provide hypothetical values in order to be more explicit about how workers may contribute to output. In Table A.2 we present a hypothetical firm that has slowly increased the number of workers (from zero to four workers) and recorded how much total output was produced (zero to 37 units). Generally speaking, more workers produced more. For example, two workers produced 25 units of output; four workers produced 37 units.

Table A.2: Average product of labour (holding capital constant)

Labour (number of workers)	Output (units)	Average productivity of labour (units of output)
0	0	-
1	10	10.0
2	25	12.5
3	32	10.6
4	37	9.25

[26] A plausible hypothetical explanation of this observed effect is that arrests in violent incidents are more likely to rely in the physical intervention of police officers and confrontation with suspects, and less likely to rely on administrative work and scenes of crime activity.

We are most interested in the last column. The last column of the table shows how much each worker contributed, on average, towards the total output. With one worker, the average amount produced per worker was 10 units. With the second worker on board, the average amount produced per worker was 12.5 – by adding that second worker, the average amount produced by the first worker actually increased (from 10 to 12.5). Now, examining the last row, each of the four workers produced on average 9.25 units; for the first worker, this is even less than when that worker worked alone and produced 10 units.

Importantly for building a workforce, we see that adding more workers may produce more output overall; however, the amount that each person can produce may actually fall.

A.2.3 Marginal output per worker

The next concept we need to introduce is the marginal product of labour, or the amount of output for an *additional* employee. The marginal product of labour is the change in output resulting from hiring an additional worker, holding constant the quantities of all other inputs (Borjas, 2005). That is, supposing there are no changes to the number of cars or buildings a police force owns (no change in capital), marginal productivity of the workforce is equal to the value added by one additional employee.

Using the same values for the number of workers and output from the previous table, we introduce the concept of marginal product in Table A.3. We see that adding the first worker generated 10 units of output; the second employee added 15 units of outputs; the third produced only an additional 7 units of output. All four employees together produced 37 units.

Table A.3: Marginal productivity of labour (holding capital constant)

Labour (number of workers)	Output (units)	Marginal productivity of labour (units of output)
0	0	-
1	10	10
2	25	15
3	32	7
4	37	5

A.3 Demand shocks

An unexpected, temporary increase or decrease in demand is a 'demand shock'. In Figure A.2, we demonstrate a shock in demand in which the initial supply and demand for policing was in equilibrium with a price of P_0 and quantity of Q_0. Then a shock in demand occurs, such as a terrorist attack, and there are more people willing and able to fund policing at every price than before the shock. So, demand shifts outward and to the right; we have a greater quantity of policing supplied and demanded, Q_1, at a higher price, P_1. The price increased in order to induce more supply of police to address the critical situation.

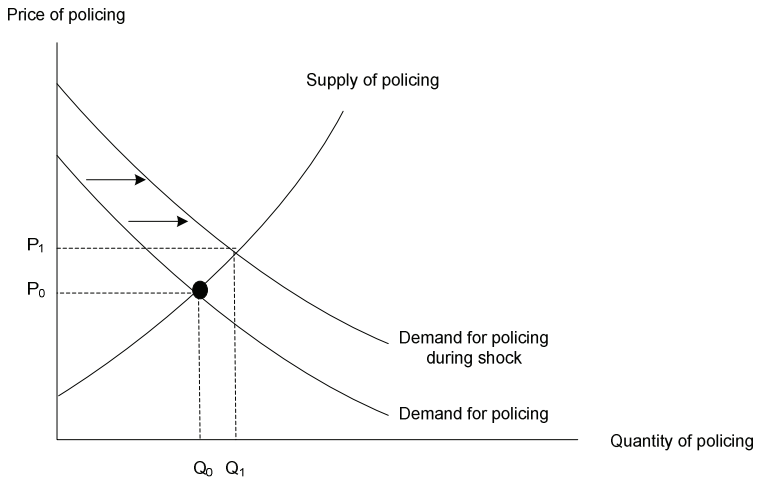

Figure A.2: Illustration of a demand shock

APPENDIX B: Econometric analysis of workforce resilience

B.1 Introduction to the econometric modelling

We estimate two different relationships in order to understand two issues related to resilience – the level of the police workforce and the level of demand for crime, and the ratio of police officers to staff and its relationship to demand.

In the first case, we estimate crime and workforce levels for minimum and maximum states of resilience and a median (moderate) resilience point. This last point is estimated by considering the evolution of police officer levels and crime levels over time, under the assumption that the system does not receive any shocks that could alter the equilibrium. We use the predator–prey model borrowed from biology as a useful analogy in this context. The aim of using this model is to understand the long run steady state in order to estimate the equilibrium level between the number of recorded crimes and the presence of police officers in England and Wales. We also estimate extreme states of resilience. From this modelling activity we are able to show the necessary police officer levels in order to keep crime at a constant level, and the number of police officers necessary to defeat crime. In addition we use the modelling activity to compare three strategies aimed at minimising the social cost of reducing police workforce numbers. The second modelling activity seeks to understand whether the composition of the police workforce, in police officers and staff, influences the reduction of crime levels. Specifically, we analyse the impact of changes in the police officer to police staff ratio and the reduction of violent crime and burglary.

B.2 Theoretical model

To describe the evolution of police forces and level of crime, we use a model borrowed from biological scientific literature; in biology, dynamic systems are used, for example, to describe the population evolution of a predator and its prey (Berryman, 1992; Kramer and Drake, 2010; Peng et al., 2010).

The predator–prey model is used to understand whether a species is endangered or whether a long-run equilibrium (also known as steady-state) of both populations exists. In our case, police forces represent the predator that 'needs' crime to 'survive' and to grow; on the other hand crime is the prey population that, if not diminished by the police predators, will continue to grow.

The use of predator–prey models in crime is not entirely unprecedented. A study sets forth the theoretical parallels between the predator–prey model in biological terms and the relationship between muggers (the predator) and muggees (Neher, 1978). The author argues that muggers and muggees have a similar relationship to fisherman and fish, and over-mugging can occur in the same way as over-fishing.

We use crime and police workforce data to estimate the relationship between predator and prey populations over time. The results of our estimation will depend on the particular assumptions we make about the way crime behaves as police resources rise and fall. Having considered all the available empirical evidence, we assume that if there are no police, the level of recorded crime will not behave as an exponential function (e.g. explode over time), but as a curve that explodes at the beginning, has the highest increase in the initial periods, and then stabilises over time as alternative social control mechanisms kick in.

We estimate two sets of models – one set examines states of resilience and one set examines the ratio of police officers to staff. In this section, we develop the empirics behind each of these and discuss the key assumptions.

B.2.1 Models for states of resilience

Systems such as that of predator and prey can be modelled by the following system of two equations:

$$\begin{cases} P_{t+1} = k_1 + \alpha P_t + \beta C_t + \varepsilon_t \\ C_{t+1} = k_2 + \gamma P_t + \delta C_t + v_t \end{cases},$$

where P_t is the aggregate number of police officers[27] in England and Wales at time *t* and C_t is the level of crime[28] at time *t*. The parameters to be estimated are $k_1, k_2, \alpha, \beta, \gamma,$ and δ. ε_t and v_t are two error terms assumed to be identically and independently normally distributed with zero mean and constant variance and unrelated with the regressors.

The constant term k_i has a dual role in this model. It will be used to determine the growth rate of:

- police forces when there is no crime (maximum resilience)
- crime when there is no police (minimum resilience).

Denoting the estimation of the parameter with a *hat*, $\hat{\square}$, the joint use of k_1 and α on one side and of k_2 and δ on the other side is useful to obtain the estimated growth rate of police forces and crime level when the level of crime and police are set to zero respectively:

$$\frac{\hat{P}_{t+1} - P_t}{P_t} = \frac{\hat{k}_1}{P_t} + (\hat{\alpha} - 1)$$

[27] It includes ACPO ranks, superintendents, chief inspectors, inspectors, sergeants, constables and secondments.

[28] It includes all type of crime recorded by the police: violence against the person offences, sexual offences, robbery offences, burglary, offences against vehicles, other theft offences, fraud and forgery offences, criminal damage offences, drug offences and other miscellaneous offences.

$$\frac{\hat{C}_{t+1} - C_t}{C_t} = \frac{\hat{K}_t}{C_t} + (\delta - 1).$$

The other parameters have the following roles:

- β represents the impact rate of crime at time *t* on the police force at time *t+1*.
- γ represents the impact of police forces at time *t* on crime level at time *t+1*.

B.2.2 Models for the police officers to police staff ratio and crime

Two different models are used in order to understand which type of police labour (police officers, police staff) have the highest impact on two different types of crime:

- violence against the person offences
- theft offences.

In particular, we model crime as a function of the number of police. The first set of regressions identifies how much each type of police (officer and staff) can influence the number of violent and theft crimes:

$$V_t = \alpha + \delta t + \beta S_t + \gamma \overline{S_t} + \varepsilon_t$$

$$T_t = \alpha + \beta S_t + \gamma \overline{S_t} + \varepsilon_t,$$

where V_t is the number of violent crimes recorded at time *t*, T_t is the number of theft crimes recorded at time *t*, S_t is the number of police officers at time *t*, and $\overline{S_t}$ is the number of police staff at time *t*. A dummy variable is also included to take into consideration that in 1998 the recording practices for crime changed.

In an initial step to identify the best specification of the model for these factors, we tested each of the time series (for the two different types of crimes) for stationarity; we need the series to be stationary to be reliable. We find the series are not stationary and yet the Dickey-Fuller tests indicate that it is possible to statistically correct the series to achieve stationarity. The Dickey-Fuller tests indicate that adjusting for the trends over time will achieve stationarity.

We go one step further and perform the Johansen cointegration test to see if including a trend in each equation will achieve stationarity, as proposed by the Dickey-Fuller tests. The Johansen cointegration test finds adding a time trend to the equation for violence against the person will achieve stationarity. The Johansen cointegration test finds it is not actually necessary for the equation on theft offences; the constant term is sufficient to make the series stationary.

Another set of tests finds the two regressions are correctly specified and the key assumption of the OLS technique is not violated; specifically, the error terms are independently and identically normally distributed. If, however, the regressors are correlated with the error term (e.g. endogeneity is present), the estimated parameters could be biased and not consistent.

Lastly, we consider that the relationship between number of officers and crime is lagged such that previous situations influence crime later on. We therefore use an Autoregressive

Distributed Lag (ADL) model with one period lag (e.g. ADL(1,1)). This tries to validate the results from above and is formally the following:

$$Y_t = \alpha + \varphi_0 S_t + \varphi_1 S_{t-1} + \gamma_0 \bar{S}_t + \gamma_1 \bar{S}_{t-1} + \theta Y_{t-1},$$

where the instantaneous impact multiplier is represented by φ_0 and γ_0, and the long run multiplier is given by $\frac{\varphi_0 + \varphi_1}{1-\theta}$ and $\frac{\gamma_0 + \gamma_1}{1-\theta}$.

B.2.3 Key assumptions

First, we start with the assumption that the police workforce levels this year are only associated with the crime levels of this year. The technique we use is called an Ordinary Least Squares (OLS) estimation and is standard for producing estimates of the short-run relationship between factors. However, the underlying assumption may not hold; it may be that the level of crime, say, three to five years ago determines current levels of resource.

Therefore, we relax the assumption that police and crime are only contemporaneously correlated by also considering lagged effects – those that take some time to appear. This is the ADL modelling repression approach. It considers the long-run relations between variables and takes into account that the levels of the previous year can influence the levels this year. In effect, this technique provides an estimate of the contemporaneous association between the number of police officers and recorded crime, as well as the long-run relationship between police officers and crime.

Lastly, a key underlying assumption so far has been that where we observe police force levels and crime levels moving together, changes in one variable will directly lead to changes in the other. However, this may be a relatively risky assumption – it may be that other contextual factors influencing police levels and crime levels are responsible for the apparent relationship such that when police levels rise so do levels of crime. The danger in this situation is that the contextual factors producing the effect are unknown and may be transitory in time and place. If this is indeed the case then attempts to replicate the findings or generalise the assumed relationship to other situations may be doomed to failure. In order to deal with this possibility, we perform what is formally known as cointegration analysis. It is an advanced estimation technique that takes into account additional sources of uncertainty in the relationship between variables such as the one described above. There are additional benefits to performing cointegration analysis – less data are needed and the estimation suffers less from the presence of endogeneity.

B.3 Data

The data set for police numbers is provided by Mulchandani and Sigurdsson (2009) and for crime levels is provided by Walker et al. (2009). We cover the period 1996–2008.

B.3.1 Data description

The number of violence against the person offences (recorded) has been increasing since 1996, as illustrated in Figure B.1, while recorded theft offences have been decreasing. This may be due to changes in recording practices, changes in policing strategies, or actual changes in crime.

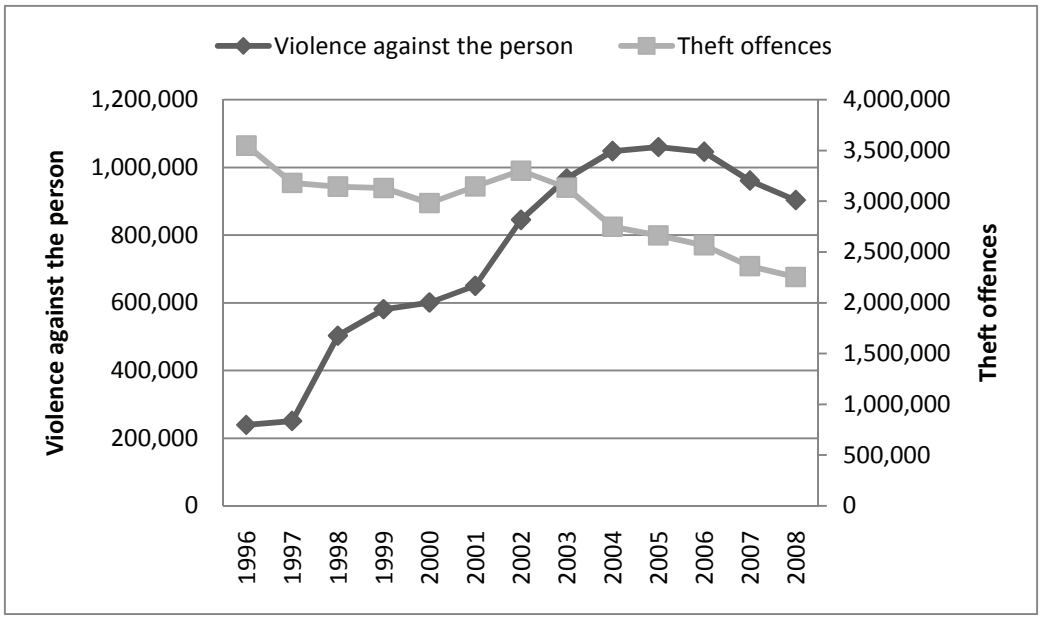

Figure B.1: Recorded levels of violence against the person and theft offences, 1996–2008

Source: Walker et al. (2009).

It may be that these changes are due to changes in the number of police officers and staff. Figure B.2 shows the ratio of police officers to staff has been falling during this period of increasing violence against the person and fall in thefts (there is an increase in staff and relative fall in officers).

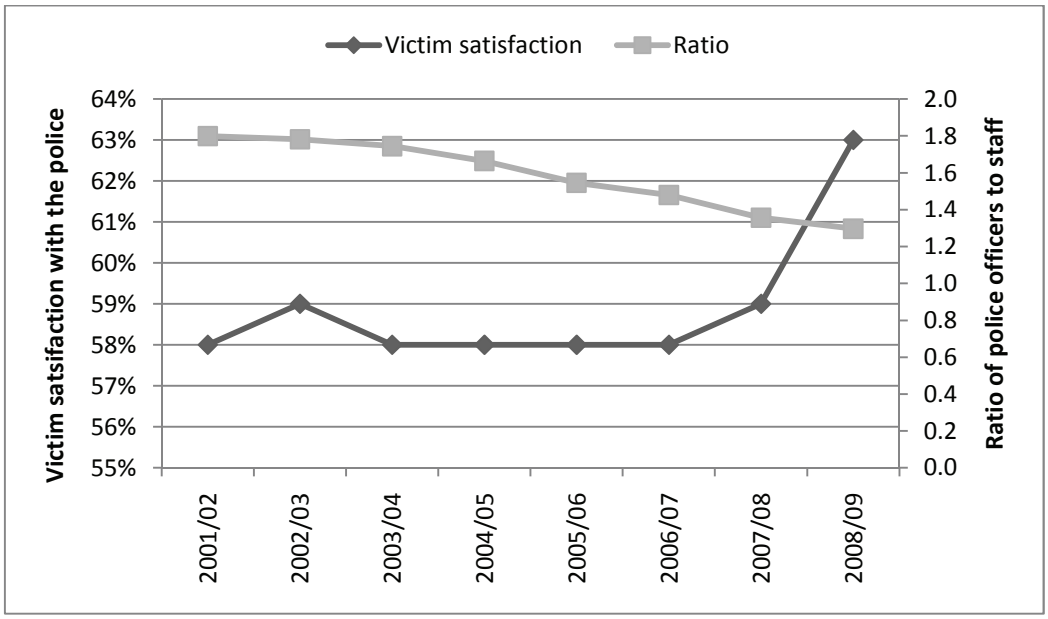

Figure B.2: Ratio of police officers to staff and victim satisfaction with police, 2001/02–2008/09

Source: Ratio based on Mulchandani and Sigurdsson (2009); satisfaction with police based on Walker et al. (2009).

Generally, the data present two points that need clarification:

1. In 1998 the way in which crime is recorded changed, resulting in a higher level of violent offences and theft offences after 1997.
2. The distinction between police officers and police staff is problematic as a special type of police, *secondments*, could be either police officers or staff; in our analysis we will consider secondments as police officers.

Regarding the first point, we calculated the difference in 1998 with the old and new recording practice. Total recorded crime is 14 per cent higher using the new definition. Since our estimations use two years of older definition (1996 and 1997) and 11 years of the new definition (1998–2008), the bias is fairly limited. An interesting improvement of this study will be to adjust for the change in recording and re-estimate the models to see how this affected results. Furthermore, we could then provide government with an understanding of how influential this change in recording has been on other analyses that did not adjust for the change in recording. It was beyond the scope and resources of this study to estimate everything twice in order to demonstrate statistical bias; however, as a first step, we estimate the second model for the ratio of police officers to staff and crime types adjusting for the change.

As to the second point, the use of secondments, this does not appear to be a significant problem. The last column of Table B.1 shows that Ratio A, which includes secondments as police officers, is about 1–5 per cent greater than Ratio B, which counts secondments as police staff.

Table B.1: Ratio of police officers to staff, 1996–2008

Year	Ratio A*	Ratio B**	Difference between Ratio A and B
1996	1.65	1.58	4.4%
1997	1.65	1.58	4.5%
1998	1.69	1.62	4.4%
1999	1.73	1.65	5.0%
2000	1.76	1.68	5.0%
2001	1.80	1.71	5.0%
2002	1.78	1.70	5.1%
2003	1.74	1.68	4.1%
2004	1.66	1.60	4.1%
2005	1.55	1.50	3.2%
2006	1.48	1.44	3.1%
2007	1.36	1.35	0.8%
2008	1.30	1.29	0.8%

Source: Authors' calculations based on Mulchandani and Sigurdsson (2009). A value greater than one indicates more police officers than police staff; *secondments considered police officers; **secondments considered police staff.

In order to understand whether there are further problems with the data and to ensure robustness of our estimates, we perform a number of tests on the data.

In this section, we describe the results of those tests, and discuss a number of limitations.

B.3.2 Cointegration

In time series analysis, it is important for robustness to check for stationarity. If one does not correct for this, the relationship found in the regression will not be meaningful and will be spurious.

Using the Johansen cointegration estimation,[29] the constant term k_i is necessary to make the series stationary. We include this in our estimations.

We also include the time trend, as specified by the Johansen technique, and lagged dependent and independent variables to mitigate the problem of non stationarity.

The model captures the short-term and long-term relationship of the two types of police forces on violent offences and theft offences (each offence is represented by the Y_t in the above equation).

B.3.3 Contemporaneous correlation

More generally for correlation between variables, we test whether there is any relationship between the level of police officers and crime.

When we consider contemporaneous adjustment between police officers and level of crime, the two series are weakly correlated ($\rho = 0.10$).

When we take into consideration that police officer levels adjust to crime levels after one year, the correlation increases to $\rho = 0.50$. Meaning, police officer levels respond to levels of crime in the previous year.

When we consider that police officer levels adjust to crime levels of two and three years ago, the indicator increases further to $\rho = 0.81$ and $\rho = 0.90$, respectively.

This means that, at present in 2009, the number of police officers does not efficiently reflect the demand. This is because police officer levels now are responding to the crime situation of three years ago. Putting this the other way about, if crime levels fall then the police workforce will not reflect this fact for three years. However, this does not necessarily mean that the optimal strategy of policy makers is to make the level of police officers perfectly responsive to crime movements.

B.3.4 Limitations

The outputs show that our model does not suffer from autocorrelation, heteroscedasticity, non-normality of the errors term, or misspecification. However, these results, as well as the test on stationarity, depend on the sample size and we arguably have a small sample size. The accuracy and reliability of the results could be improved with a longer time series.

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[29] While the Dickey and Fuller test rejects the hypothesis of stationarity even in the presence of a constant term, the Johansen technique shows that in the presence of a constant term the long run matrix is of full rank and hence the series can be considered stationary.

Furthermore, our results may suffer from some bias. The two possible sources of bias in the results are:

- endogeneity: if endogeneity exists, the estimated parameters could be biased
- non-normality: if the true error terms do not have zero mean, the intercept terms are biased.

B.4 Results of the first model: states of resilience

B.4.1 Steady-state resilience

According to the previous model and using OLS technique the following estimation is obtained:[30]

$$\begin{cases} R_{t+1} = -12419.65 + 0.919R_t + 0.004C_t \\ C_{t+1} = 3814860 - 24.514R_t + 0.88C_t \end{cases}.$$

The first set of results (in Table B.2) indicates that past crime and past police officer levels influence the level of police officers today. In particular, increasing the number of police officers by one last year is associated with increasing the number of police officers by 0.92 this year. Essentially, there is a correlation between years meaning that the number of police officers hired in a year depends, in part, on the number that were hired in the previous year.

Table B.2: Regression results on factors of police

Dependent variable: number of police officers	Coefficient	Std error	p-value
Constant	−2,419	9,748	0.23
Police (−1)	0.92***	0.07	0.00
Crime (−1)	0.00***	0.00	0.00
R-squared	0.95	Prob > F	0.00
White	0.98	JB	0.78
Ramsey	0.16		

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

The second set of results (see Table B.3) indicates that increasing the number of police officers last year by one reduces the number of recorded crimes this year by approximately 24 (this result is significant at the 5 per cent level).

Table B.3: Regression results on the factors of crime

Dependent variable: level of recorded crime	Coefficient	Std error	p-value
Constant	3,814,860*	1,717,696	0.05
Police (−1)	−24.51**	12.59	0.08
Crime (−1)	0.88***	0.21	0.00
R-squared	0.62	Prob > F	0.01
White	0.70	JB	0.81
Ramsey	0.42		

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

[30] These are underestimates since the crime record method changed in 1998.

If there are no shocks in the system (and hence the series continues to move in future as it moved in the past), there exists a steady-state or equilibrium level at which the police workforce will number 130,559 and the crime level will be 5,123,854 for ever.

Testing the fit of our model

In order to know how well our model behaves, we tested a number of specifications[31] and we present results of the model with the best fit. Thus models can be tested to see if variables are 'worth' including. Models that have too many variables that do not explain anything will not perform well in testing – test statistics will be too low or too high, depending on the statistic.

It is interesting to note that according to the estimation an optimal number of police officers exists such that structural crime[32] is deterred. By structural crime, we mean the 'core' level of crime that cannot be altered by more or fewer police. So it is interesting that the optimal level of officers can actually shift what appears to be the core level of crime.

In order to find this optimal number, it is sufficient to set the crime level at time *t+1* and *t* in the second equation to zero and allow the model to estimate the required police workforce level. The model finds the optimal level is 155,616 police officers. Formally, it is expressed as:

$$^{s}\hat{R}_t = -\frac{\hat{k}_2}{\hat{\gamma}} = 155616 .$$

In general, the minimum level of police officers $\left(^{m}\hat{R}_t\right)$ required to keep the crime level constant is given by the following expression:[33]

$$^{m}\hat{R}_t = \frac{(1-\hat{\delta})C_t - \hat{k}_2}{\hat{\gamma}} .$$

This translates into the following three conditions:

$$\begin{cases} C_{t+1} < C_t \ \ if \ \ R_t > {}^{m}R_t \\ C_{t+1} = C_t \ \ if \ \ R_t = {}^{m}R_t \\ C_{t+1} > C_t \ \ if \ \ R_t < {}^{m}R_t \end{cases} .$$

In words, the first condition states that if the level of police officers is greater than the minimum level necessary to keep crime constant, then the next period's crime rates will be lower than this period's crime rate; and vice versa (the third condition).

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[31] A model with no constant in the first equation and also a two simultaneous equation model where the order and rank condition is satisfies for identification:

1) $\begin{aligned} R_{t+1} &= k_1 + \alpha R_t + \beta C_t + \varepsilon_t \\ C_{t+1} &= k_2 + \gamma R_{t+1} + \delta C_t + v_t \end{aligned}$ and 2) $\begin{aligned} R_{t+1} &= k_1 + \alpha C_{t+1} + \beta C_t + \varepsilon_t \\ C_{t+1} &= k_2 + \gamma R_{t+1} + \delta R_t + v_t \end{aligned}$.

[32] The structural crime could be represented by the constant term k_2.

[33] It is sufficient to set $C_{t+1} = C_t$ and solving for R_t in the second equation.

In order to identify whether our estimations perform well, we test how well the indicator for the minimum level of police officers ($^{m}P_t$) satisfies the above conditions. Table B.4 presents the result of tests for each year, showing whether our estimations satisfy the above conditions. For example, in 1994 the number of police officers was 127,897 and the indicator value for the minimum number of police officers needed to be 130,016 (based on the crime levels of 1994 and 1995). Since the true number of officers in 1994 was lower than the $^{m}P_t$ level, our model should have estimated that the crime level in 1995 would have been higher than that in 1994; instead it was lower. For this reason, we indicate in the last column ('Condition satisfied?') that 'No' the model did not forecast the appropriate level of crime and the conditions was not satisfied. In 1998, however, the level of crime increased as the model forecasted.

Table B.4: Minimum police force necessary to keep crime constant

Year	Police officers	Recorded crimes	Indicator value for minimum police	Condition satisfied?
1994	127,897	5,252,980	130,016	-
1995	127,222	5,100,241	130,760	No
1996	126,901	5,036,552	131,071	No
1997	127,158	4,598,357	133,206	No
1998	126,814	5,109,089	130,717	Yes
1999	126,096	5,301,187	129,781	Yes
2000	124,170	5,170,843	130,416	No
2001	125,682	5,525,024	128,690	Yes
2002	129,603	5,974,960	126,497	No
2003	133,366	6,013,759	126,308	Yes
2004	139,200	5,640,573	128,127	Yes
2005	141,230	5,556,513	128,537	Yes
2006	141,381	5,427,558	129,165	Yes
2007	140,514	4,951,173	131,487	Yes
2008	140,230	4,702,468	132,699	Yes

Generally speaking, our tests indicate that our model does not forecast the early periods, but that the later years are appropriately forecasted. This is probably due to the different recording rules used during the early period, as it does not perform particularly well before 1998; after 1998, the estimations improve and nearly all points satisfy the conditions from 1998 onwards. Importantly for this study, the forecasts going forward use the same recording that has been in place since 1998; thus, we are confident our results are reliable based on how levels of crime are currently recorded.

B.4.2 Minimum resilience

Findings suggest that the estimated growth rate of the police workforce when no crime exists is 17.8 per cent in the first year. Perhaps more interestingly, the estimated growth rate of crime when there is no police is 69.2 per cent in the first year.

One interpretation of these results is that police numbers do have an effect on recorded crime even though simple descriptive statistics suggest this is not the case. Figure B.3

shows the estimated growth rate of crime under the assumption that from 2008 onwards no police forces exist.

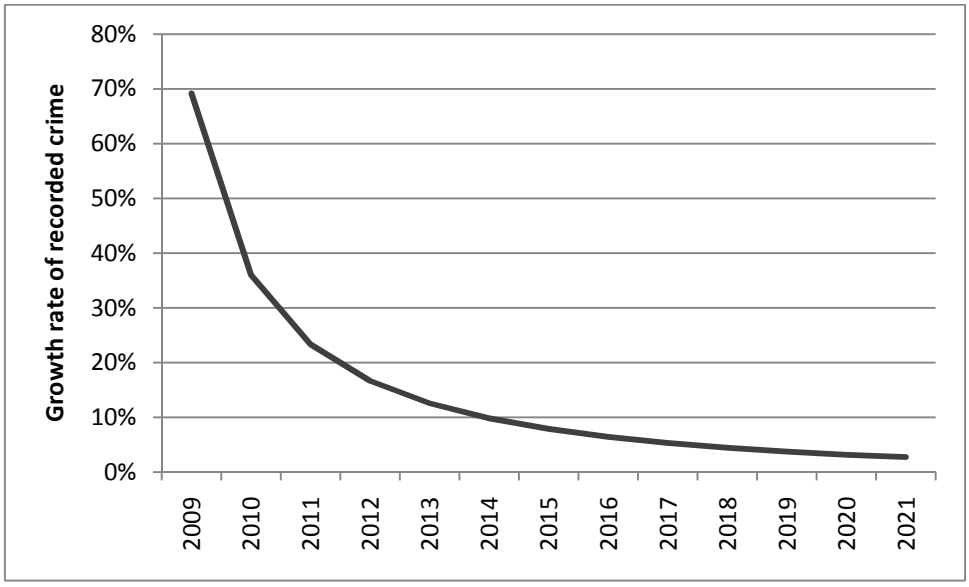

Figure B.3: Expected crime growth rate (no police force assumption)

As Figure B.3 shows, the crime growth rate is greatest in the first year and then it stabilises into a long run level approximately ten years later.

B.4.3 Maximum resilience

According to our estimation thus far and under the assumption that no shock will happen in future, the system will reach a steady state equilibrium that is not optimal since a high level of crime is reached.

It is possible to determine all future levels of crime.[34] We show the equation one year in the future, two years into the future, through to the general equation for all years into the future:

$$C_{t+1} = k_2 + \gamma R_t + \delta C_t$$

$$C_{t+2} = k_2(1+\delta) + \gamma R_t(1+\delta) + \delta^2 C_t$$

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$$C_{t+\omega} = k_2 \sum_{i=0}^{\omega-1} \delta^i + \gamma R_t \sum_{i=0}^{\omega-1} \delta^i + \delta^\omega C_t \quad .$$

It is possible to determine the optimal level of police that guarantees zero recorded crime after ω periods. The equation is:[35]

[34] The *hat* on each parameter will be dropped for convenience.

$$ {}^{\omega}P_t = -\frac{k_2}{\gamma} - \frac{\delta^{\omega}}{\gamma \sum_{i=0}^{\omega-1} \delta^i} C_t . $$

In words, this equation means that if we wish to have zero crime after ω periods then it is sufficient that the following occur:

- the number of police should be equal to ${}^{\omega}P_t$ for ω periods and then
- the level of police $P_t{}^{s}$ needs to be maintained in perpetuity thereafter.

In conclusion, a zero level of crime can be reached after ω periods and in perpetuity if the conditions below are satisfied:

$$ \begin{cases} P_t = {}^{\omega}P_t \ \ for \ 0 \leq t \leq \omega \\ P_t = {}^{s}P_t \ for \ \omega + 1 \leq t \leq \infty \end{cases} . $$

Table B.5 presents our results and shows the size of police workforce necessary in order to achieve zero crime after ω periods.[36] It also shows that, if $|\delta| < 1$, there exists a critical police workforce level under which the number of police officers should not fall in order to guarantee a zero crime level in future; this level is exactly the one that deters structural crime, i.e. ${}^{s}P_t$.[37] In particular, to defeat crime in one year, the police force level should not fall below 324,523 police officers. To defeat crime in 145 years, the police force level should not fall below 155,616 police officers; a level which is 11 per cent more police officers than in 2008.

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[35] It is sufficient to set $C_{t+\omega} = 0$ and solve for P_t.

[36] The value of crime in 2008 was taken for the computation.

[37] If $|\delta| < 1$, as ω increases ${}^{\omega}P_t \to -\frac{k_2}{\gamma}$ because the second term $\frac{\delta^{\omega}}{\gamma \sum_{i=0}^{\omega-1} \delta^i} C_t \to 0$.

Table B.5: Number of police officers needed to defeat crime in 1–145 years

Year	Police officers
1	324,523
2	234,704
3	204,925
4	190,156
5	181,389
6	175,622
7	171,568
8	168,584
9	166,312
10	164,537
11	163,122
…	…
…	…
…	…
145	155,616

B.4.4 Comparing strategies to achieve zero crime: what is the optimal strategy?

The hypothetical state in which police workforce levels are high enough to eliminate crime may not seem relevant or useful to police managers and policy makers: the workforce levels required are unrealistically high. However estimates of this state do serve a practical purpose in workforce planning. Knowing about extreme levels provides managers with a benchmark against which to compare current levels and possible future levels. In order to make our estimation of the extreme case of zero crime more useful to workforce planners, we also take costs and time frames into consideration. This allows us to discuss an optimal strategy for managers and policy makers to adopt in order to achieve zero crime. Now suppose police managers and policy makers want a maximum level of resilience so as to defeat crime. In order to do this, they are given unlimited resources (e.g. they can hire as many police as they want). However they have to choose how many years to take to reach their objective. In order to choose the number of years, managers should consider the associated costs. Suppose the cost per police officer is φ and this value includes all direct costs of hiring the police officer, such as earnings, pension payments, equipment, cost per police officer for the station building, car and so on. We do not include indirect costs, such as the social cost of crime or victimisation cost. We do, however, consider the cost of money over time so we introduce an interest rate "i" in order to be able to compare future costs with current costs.

To start, we compare two strategies:

- defeating crime in year 1 and in year 2
- defeating crime by year 2.

Formally, this is represented by the following two equations:

$$Cost_1 = 324523\varphi + \frac{155616}{(1+i)}\varphi$$
$$Cost_2 = 234704\varphi + \frac{234704}{(1+i)}\varphi .$$

It is the case that no positive interest rate[38] exists such that the first strategy costs less than the second one. If we do not include the cost of victimisation, the second strategy should be preferred from an economic point of view because it always dominates (e.g. is more cost-efficient than) the first one.

But there is also a third possible strategy – since the future costs less than the present, we might choose to have no police in the starting year (which we call year 0). As a consequence, the level of crime increases dramatically in year 1 but there are also dramatic savings. In year 2 the level of police officers is increased to a level that will defeat crime in the second year.

As to particular numbers, with no police officers in 2008 (the starting year), then the number of criminal offences in 2009 would increase to 7,955,512; a nearly 70 per cent increase. Then, in order to reduce crime to zero in 2010 the police force in 2009 should be 441,367. Formally, the equation being estimated is:

$$Cost_3 = 0\varphi + \frac{441367}{(1+i)}\varphi .$$

This last strategy not only dominates the first one, but also the second one: it is more cost effective to severely reduce the number of police officers, even if crime increases, in order to save and invest the money. If this investment is later applied to increasing police numbers in order to correct the rise in crime, there will still be savings achievable from the sums invested plus accumulated interest.

Results of second model: the relationship between police officer and police staff levels

Our results indicate that the number of police officers is associated with increases in the number of violent offences recorded; specifically, increasing the number of police officers by 1 increases the number of violent offences recorded by 33 (see Table B.6). On the other hand, increasing the number of police staff is associated with a decrease in the number of violent offences recorded.

[38] It does not depend on φ since this term cancels out.

Table B.6: Regression results for violent offences recorded

	Coefficient	P > t
Constant	−2,859,267***	0.000
Recording data dummy	176,821***	0.000
Time trend	45,673***	0.000
Number of police officers	33.13***	0.000
Number of police staff	−15.21***	0.000
R-squared	0.99	
Durbin-Watson	2.56	
Ramsey (Prob > F)	0.27	

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

We find the relationship between the number of police officers and the number of thefts recorded is not statistically significant (see Table B.7). As in the case of violence, we find that more police staff are associated with fewer recorded thefts.

Table B.7: Regression results for theft offences recorded

	Coefficient	P > t
Constant	4,990,984***	0.002
Recording data dummy	−356,530**	0.013
Number of police officers	2.97	0.818
Number of police staff	−26.00***	0.003
R-squared	0.90	
Durbin-Watson	2.32	
Ramsey (Prob > F)	0.64	

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

Generally, both of these models have very high goodness of fit (a high value of R-squared) and a high Durbin-Watson (DW) test statistic, indicating the two regressions are not spurious and the results are meaningful. However, these findings are difficult to interpret and there is an obvious case for further testing under different assumptions. We have already established that the relationship between police and crime is lagged – it takes years for crime to respond to police force levels. Thus far, in the analysis of the levels of crime and the staff–officer ratio, we have only considered the contemporaneous relationship. It may be that if we take into consideration the way the past is influencing the present, we will achieve different results.

Therefore, we use an ADL regression model as described in the empirical section to capture the short-term and long-term relationship of the two types of police workforces on violent offences and theft offences. In other words, the ADL (1,1) regression model considers the contemporaneous (e.g. short-run) and lagged (e.g. long-run) relationships.

These results show that, in part, previous results were invalid because there is an important relationship between current levels of crime and the number of police staff. As Table B.8 shows, the presence of police staff does not have an instantaneous impact on the reduction of crime, but it does have an impact in the long run. Police officers continue to have a statistically significant influence in increasing the number of violent offences recorded.

Table B.8: Summary of results, relationship between crimes and police officers and police staff

	Police officers		Police staff	
	Violent	Theft	Violent	Theft
Short run multiplier	26.84	0.00	0.00	0.00
Long run multiplier	29.56	0.00	−8.34	0.00

Although a trend term is sufficient to make the regression stationary and to create reliable results, if we do not include a constant term the series are not stationary. In this case, without a constant term, the Johansen cointegration test indicates that neither police officers nor police staff have an effect in the long run on the number of violent crimes recorded. A cointegration relationship was not found in the case of theft offences and results remain uncertain.

Since cointegration analysis gives the most consistent results and suffers less from the problems of misspecification or endogeneity, we can argue that these two types of police workforce do not have a statistically significant impact on reducing violent crime. Strong uncertainty still surrounds the outcome of the analysis of theft offences.

Although it is beyond the scope of this study to test the idea, it is plausible to argue that violent offences are particularly prone to pushing up the demand for policing and being recorded by patrolling officers. A finding that violent crime is correlated with officer numbers is thus difficult to interpret. The same is not true of acquisitive crime: where stolen goods are insured, reporting rates are driven by insurance claims rules not by the availability of police officers. To make sense of the above findings, it would be necessary to distinguish between willing and unwilling reporters of violence (those who would report an incident whether or not a police officer was involved and those who would not). There are no data available on this subject; however, A & E records show that there are many more non-self-inflicted bodily injuries treated (some of which are caused by violence) than there are reports to the police of violence against the person; this indicates that not all violence is reported to the police. Insurance data would also allow a comparison of insurance driven reports of acquisitive crime and other reports.