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The Provision of Local Public Services in a Risky Environment: An Application to Crime

by Stefan Traub

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The Provision of Local Public Services in a Risky Environment: An Application to Crime

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Abstract

We state efficiency conditions for the provision of congestable local public goods that diminish individual-specific proprietary risks. The optimum level of such a public service is determined by equating the sum of the reductions of the expected property losses due to a better service level with the marginal costs of the service. The optimum size of the providing local authority in terms of population is obtained where the increase in proprietary risks due to congestion meets the decrease in contributions for the original citizens. As an empirical example, we employ Germany's crime statistic in order to assess the efficiency of the provision of police services at the state level.

Keywords: Local Public Goods, Congestion, Risk, Crime, Police
JEL-Classification: H41, D61, R50

1 Introduction

Between the polar cases of Samuelson's (1956) pure public goods and private goods, there is a multidimensional spectrum of impure public goods. In textbook economics (for example, in the definitive book by Cornes and Sandler, 1986), we usually focus on the degrees of divisibility and excludability of benefits. An alternative way to distinguish between different categories of

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public goods is to look at the different channels through which they make an impact. In a recent paper, Lohse et al. (2005) broadened the topology of public goods by uncertainty: some public goods do not directly contribute to the benefits of their users. Actually, these goods reduce the probability and/or the size of a potential damage (on the distinction see Ehrlich and Becker, 1972). According to Lohse et al., typical textbook examples such as lighthouses, national defense, or fire departments belong to either category. For instance, a lighthouse is a navigation aid that prevents sea damage, whereas firemen will take great pains to keep fire losses as small as possible.

In this paper, we consider local public services that diminish individual-specific proprietary risks. It is assumed that the benefits of the publicly provided good remain within the city limits, that is, spillover effects are negligible. Though it may be technically possible to exclude several citizens from the consumption of the service, doing so is not desired for political reasons. For a given level of provision, an increase in population will abate the quality of the service for the original citizens. People cannot vary their utilization rates. However, the population may be heterogenous as to the actual size of the benefit in terms of risk reduction. A typical example for such a public service is the police. The police prevent and detect crime. As households differ in their endowments (property, location within the city, etc.), they also differ in their exposure to crime.

The paper is organized as follows. In the next section, we briefly review the relevant literature. The model is introduced in Section 3. Efficiency conditions are derived in the fourth section. Section 5 presents the empirical application. Section 6 concludes the paper.

2 A Brief Literature Review

In his pioneering article "The pure theory of public expenditure" and its subsequent "Diagrammatic exposition" Samuelson (1956, 1957) formulated a "polar case model of government, to be contrasted with the traditional individualistic model of general equilibrium" (Musgrave, 1983, p. 329). As Musgrave (1983, p. 330) remarked, two offsprings of the theory of public goods have received particular attention in literature. The first deals with public goods that are subject to congestion or crowding. The second is concerned with public goods whose "benefits are spatially limited" (p. 330). Oates' (1972, 1999) famous decentralization theorem deals with the latter case: from a normative view, the provision of pure public goods "the consumption of which is defined over geographical subsets of the total population" (p. 35) by local governments is always at least as efficient as the uniform provision by a central government. The pessimistic undertone in Samuelson's work as to the ability of both market and governmental institutions to allocate public funds in an optimal way prompted Tiebout (1956) to contradict. Under rather restrictive assumptions, his model comes up with an efficient solution of decentralized local public goods provision: "The consumer-voter may be viewed as picking that community which best satisfies his preference pattern for public goods" (p. 418).

In his critical assessment of the Tiebout model, Bewley (1981, p. 715) introduced the distinction between *pure public goods* and what he called *pure public services*. The first notion refers to publicly provided goods the provision costs of which are independent of population size. In the latter case, costs are proportional to population, that is, these services are essentially consumed as private goods (though provided publicly). On the one hand, Bewley (1981, p. 732) proved the existence and efficiency of Tiebout equilibria; at the same time he demonstrated that this result clings to the assumption that local governments provide public services rather than public goods. One way to overcome this problem is the assumption of a U-shaped or otherwise varying relationship between production costs and population size (see, for example, Tiebout, 1956; Buchanan, 1965; McGuire, 1974; Wooders, 1978), but "this introduces a complication in that optimal community size and the choice of public service level are interdependent" (Bewley, 1981, p. 734).

Whether the relationship between population size and local expenditures is constant, proportional, or U-shaped is a question that has to be answered empirically. Hence, it is not too surprising that a large body of literature on the "publicness" of local public goods has developed, beginning with the works of Borcherding and Deacon (1972) and Bergstrom and Goodman (1973). Though some methodological objections have been raised against their approach (Oates 1988; Reiter and Weichenrieder, 1997, 1999), the general bottom line of these studies is that most public services exhibit estimates of the congestion parameter close to 1, meaning that these goods are private (compare, for example, Table 1 in the survey by Reiter and Weichenrieder, 1997, p. 379).[1]

In our empirical application, we focus on internal security. That is, the public service to be considered is the police, which prevent and detect crime. The economic theory of crime goes back to Becker (1986) and Ehrlich (1973, 1996). Here, crime is explained as the outcome of an individually rational

[1]This result has provoked an important question: if most publicly provided goods are private, why are they provided publicly at all (compare, for example, Holcombe and Sobel, 1995)? The most obvious reason is non-excludability.

process of considering the expected benefits and costs of committing an offense. Empirical analyses of crime have been carried out, for example, by Levitt (1997), Glaeser and Sacerdote (1999), Büttner and Spengler (2003), and others. Levitt (1997) investigated the deterrence effect of police on crime. Controlling for electoral cycles, Levitt found that an additional police officer on average eliminated eight to ten serious crimes per year. He estimated that the social benefit of reduced crime was about \$ 100,000 per officer per year and reasoned that the current number of police was below the optimal level. Drake and Simper (2005) assessed the technical efficiency of police provision using a stochastic frontier approach.

The approach of Borcherding and Deacon (1972) and Bergstrom and Goodman (1973) for the measurement of crowding has been applied to the police as well. Reiter and Weichenrieder (1997) listed 9 different studies that found crowding parameters in a range between 0.64 and 2.01; yet most of them were close to 1. Borcherding and Deacon (1972) used aggregated US data at the state level, while all other studies used community level data. However, their estimate of 1.019 is perfectly in line with the other authors' results.

All these studies measured the level of the public good in terms of local public expenditures on, for example, the police. This proceeding neglects the fact that the benefits of the public service are indirect, through the reduction of proprietary (and other) risks, rather than direct. On the other hand, empirical studies of crime, such as Levitt's (1997), explicitly consider the deterrence effect of the police on crime, but they do not apply the local-public-good character of the police. In this paper, we join both strands of literature. In the following two subsections, we formulate a general model of the provision of local public goods, that diminish individual-specific proprietary risks, and derive a Samuelson condition and a membership condition for such services. Then, we employ a simplified version of the model in order to assess the efficiency of the provision of the police in Germany at the state level. We explicitly derive estimates for the marginal benefits of an additional police officers, both in terms of reduced crime rates and in monetary terms, and for the marginal costs of population due to crowding.

3 The Model

Wealth is denoted by w, $w \in \mathbb{R}_+$. $\mathcal{I} = \{1, \ldots, n\}$ is the index set of households. Each household i is threatened by a household-specific risk of losing ℓ_i of its wealth w_i with probability p^i, where $0 \leq \ell_i \leq w_i$. The probability of a loss is a function of population n and the level of a local public service G,

$G \in \mathbb{R}_+$:

$$p^i = p^i(G, n) \; . \tag{1}$$

Our sole assumption about $p^i(\cdot)$ is that it is a continuous and differentiable function, $p^i : \mathbb{R}_+ \times \mathbb{R}_+ \mapsto [0, 1]$, that is, for the single households $p^i(\cdot)$ could be increasing, decreasing, or u-shaped. For instance, if G was the level of police protection, then for most households $p^i(\cdot)$ would be a decreasing function of G and an increasing function of n, where the latter sign is explained by congestion. Yet, there may be some households, say, at the periphery of a city for which the risk of getting mugged increases as crime relocates from the city center to the outskirts.

The total cost of the local public service is an increasing function of the its level,

$$C = C(G) \; , \tag{2}$$

and it is is financed by individual taxes c^i, that is,

$$C(G) = \sum_{i \in I} c^i \; , \tag{3}$$

where $0 \leq c^i \leq w_i$. For a given G, an increase of population will reduce the contributions of the original citizens. Hence, we have

$$c^i = c^i(G, n) \; , \tag{4}$$

where $c^i_G > 0$ and $c^i_n < 0$.

We assume that households can insure themselves against losses on private insurance markets. Typical loss risks are, for example, covered by the householder's burglary insurance and the car-theft insurance. Let the insurance premium be denoted by q_i, $0 \leq q_i \leq w_i$. In case of a loss the household receives a compensation of z_i. Hence, the expected utility of household i is given by

$$\begin{aligned} EU_i \;\; &= \;\; p^i(G,n) \cdot u_i \left[w_i - \ell_i - q_i + z_i - c^i(G,n) \right] \\ &\quad + [1 - p^i(G,n)] \cdot u_i \left[w_i - q_i - c^i(G,n) \right] \; , \end{aligned} \tag{5}$$

where $u_i(\cdot)$ is the household's von Neumann-Morgenstern utility function. Note that we also must have $0 \leq q_i + c^i \leq w_i$. If the insurance contract is actuarially fair and the nonprofit condition applies, the expected compensation payment for the household must equate the insurance premium:

$$p^i(G, n) z_i = q_i \; . \tag{6}$$

Plugging condition (6) into (5) yields

$$\begin{aligned} EU_i &= p^i(G,n) \cdot u_i \left\{ w_i - \ell_i + \left[1 - p^i(G,n)\right] z_i - c^i(G,n) \right\} \qquad (7) \\ &\quad + \left[1 - p^i(G,n)\right] \cdot u_i \left[w_i - p^i(G,n) z_i - c^i(G,n) \right] \ . \end{aligned}$$

The household's optimum demand for compensation, $z^\star$, is obtained by taking the first derivative of EU_i with respect to z and then solving the first order condition

$$\begin{aligned} & u_i' \left\{ w_i - \ell_i + \left[1 - p^i(G,n)\right] z_i - c^i(G,n) \right\} \\ & \qquad = u_i' \left[w_i - p^i(G,n) z_i - c^i(G,n) \right] \end{aligned} \qquad (8)$$

for z. Since $u_i(\cdot)$ is a strictly concave function of wealth, condition (8) is equivalent to

$$w_i - \ell_i + \left[1 - p^i(G,n)\right] z_i - c^i(G,n) = w_i - p^i(G,n) z_i - c^i(G,n) \ . \qquad (9)$$

Not surprisingly, the household wants to fully insure its potential losses:

$$z_i^\star = \ell_i \ . \qquad (10)$$

4 Efficiency Conditions

In this section, we derive the conditions for an efficient provision of the local public service, with the proviso that households buy insurance on private insurance markets in an optimal way. We rewrite (7) using our result (10) which yields

$$EU_i = u_i \left[w_i - p^i(G,n)\ell_i - c^i(G,n) \right] \ . \qquad (11)$$

In order to obtain the optimal solution, a social planner maximizes a strictly concave social welfare function with respect to G and n:

$$\max_{G,n} W = \sum_{i \in \mathcal{I}} u_i \left[w_i - p^i(G,n)\ell_i - c^i(G,n) \right] \ . \qquad (12)$$

Under the assumption that the social planner cares only for the welfare of the original n citizens, the first-order conditions are given by

$$\sum_{i \in \mathcal{I}} u_i' \left[w_i - p^i(G,n)\ell_i - c^i(G,n) \right] \times \left[-p_G^i(G,n)\ell_i - c_G^i(G,n) \right] \stackrel{!}{=} 0 \qquad (13)$$

and

$$\sum_{i \in \mathcal{I}} u_i' \left[w_i - p^i(G,n)\ell_i - c_i(G,n) \right] \times \left[-p_n^i(G,n)\ell_i - c_n^i(G,n) \right] \stackrel{!}{=} 0 \ . \qquad (14)$$

As the u_i's are strictly increasing, condition (13) can be fulfilled if and only if

$$-p^i_G(G,n)\ell_i - c^i_G(G,n) = 0 \quad \forall\, i \in \mathcal{I}\ . \tag{15}$$

Summing up this expression over all citizens and using the fact that

$$\sum_{i\in\mathcal{I}} c^i_G(G,n) = C_G(G) \tag{16}$$

yields the optimum condition for the level of the public service:

$$-\sum_{i\in\mathcal{I}} p^i_G(G,n)\ell_i = C_G(G)\ . \tag{17}$$

This is a Samuelson condition for the provision of a local public service that diminishes individual-specific proprietary risks. On the left, we have the sum of the marginal benefits of the local public service. On the right, we have the marginal costs. As noted above, the level of the public good influences the marginal benefits only indirectly, via a reduction of the probability of an adverse event. For each citizen, the marginal benefit is given by this change of the probability times the loss that is involved by the event. Accordingly, the Samuleson condition states that the optimum level of the service is reached where the community-wide expected reduction of individual property losses meets the marginal costs of an additional unit of the service (for example, a policeman).[2]

Likewise, the derivative on the left side of first-order condition (14) is always positive. Hence, we must have

$$-p^i_n(G,n)\ell_i - c^i_n(G,n) = 0 \quad \forall\, i \in \mathcal{I}\ . \tag{18}$$

Reformulating (18) gives

$$p^i_n(G,n)\ell_i = -c^i_n(G,n)\ . \tag{19}$$

Since $c^i_n < 0$, this equation states that for each citizen the increase of expected property losses due to the crowding effect of an additional citizen must equal the marginal decrease of her contribution to the public service. Adding up over all (original) citizens yields the membership condition for the local authority:

$$\sum_{i\in\mathcal{I}} p^i_n(G,n)\ell_i = -\sum_{i\in\mathcal{I}} c^i_n(G,n)\ . \tag{20}$$

[2]Note that this condition requires the probability of a loss to be a decreasing function of the level of the public service for sufficiently many households. Otherwise, the marginal cost would always exceed the sum of the marginal benefits. Thus, the service should not be provided at all.

5 Empirical Application

Here, we apply our model to the provision of internal security, considering the German police as an example. After having introduced the data set in the next subsection, we proceed in three steps. First, we estimate the parameters of equation (1), which state the probability of suffering a property loss as a function of the level of public service and population. For data reasons, we have to limit our attention to the state level, that is, the 16 German "Bundesländer". We define p as the probability of becoming victim of a crime that involves a loss of property ℓ for the victim. G denotes the number of police officers and n the population of the respective state.

In a second step, we compute the marginal benefits of a police officer, that is, the expression on the left hand side of the Samuelson condition (17). We also compute the marginal congestion costs of an additional citizen, which is the expression on the left hand side of the membership condition (20). Finally, we make an attempt to assess the efficiency of the provision of internal security in Germany. Since we have to confine ourselves to analyzing only those offenses which both involve a measurable loss of property and can be fully underwritten, it would be inappropriate to use data on state expenditures on internal security in order to calculate the respective cost function (that is, the right side of the Samuelson condition and the membership condition, respectively). As a substitute for solving these conditions for the optimum number of police officers and the optimum population, we assess efficiency indirectly by computing the optimum number of police officers in per-capita terms for each state.

5.1 The Data

Our data refers to the year 2004. Table 1 reports for each of the 16 German federal states: area A in square kilometers, population n, population density n/A, and number of police officers G. Area, population, and population density are taken from the internet portal of Germany's federal statistical office (Statistisches Bundesamt, `www.destatis.de`). The number of police officers at the state level is published annually by the Statistisches Bundesamt in its statistic of public servants (Statistisches Bundesamt, 2005). The figures reported in the table refer to full-time equivalents, that is, part-time servants are weighted by their contractual working hours relative to a full-time position.

The three city-states Berlin, Bremen, and Hamburg stand out by their population density, whereas the former East German states exhibit a relatively low population density. As it is to be expected that the extent of

Table 1: Descriptive Statistics

State	Area	Population	Populat. density	Policemen
	A km^2	n	n/A	G
Baden-Württemberg (BW)	35,752	10,692,556	299	30,538
Bayern (BAY)	70,549	12,423,386	176	36,397
Berlin[a,b] (B)	892	3,388,477	3800	24,146
Brandenburg[b] (BB)	29,478	2,574,521	87	9,893
Bremen[a] (HB)	404	663,129	1640	3,342
Hamburg[a] (HH)	755	1,734,083	2296	9,716
Hessen (HE)	21,115	6,089,428	288	17,865
Mecklenburg-Vorpommern[b] (MVP)	23,179	1,732,226	75	6,586
Niedersachsen (NDS)	47,620	7,993,415	168	22,029
Nordrhein-Westfalen (NRW)	34,084	18,079,686	530	46,538
Rheinland-Pfalz (RLP)	19,853	4,058,682	204	11,106
Saarland (SL)	2,569	1,061,376	413	3,400
Sachsen[b] (SN)	18,415	4,321,437	235	15,009
Sachsen-Anhalt[b] (SNA)	20,446	2,522,941	123	10,144
Schleswig-Holstein (SH)	15,763	2,823,171	179	7,821
Thüringen[b] (TH)	16,172	2,373,157	147	7,871
German (GE) total	35,7046	82,531,671	n.a.	262,401
Mean	22,315	5,158,229	666	16,400

Table notes. [a]City state. [b]Former East Germany. All data refer to 2004. Data sources: `www.destatis.de` and Statistisches Bundesamt (2005).

crime varies with population density (see, for example, Glaeser and Sacerdote, 1999), it will be included as a covariate in the regressions of G and n on p.

Table 2 gives the probability of becoming victim of a crime which involves a loss of property, and the respective proprietary damage in Euros per capita. Figures are presented for (i) all cases, (ii) all unsolved cases, and (iii) all unsolved cases of theft. Germany's federal criminal police office (Bundeskriminalamt, 2005) annually publishes a very detailed crime statistics which is based on the states' crime statistics.[3] Their index of criminal offences is categorized into eight main groups: murder and manslaughter (group 0), offences against sexual self-determination (1), brutality and deprivation of liberty (2), theft (3 and 4), proprietary crimes and forgery (5), other offences against penal law (6), offences against other laws (7). However, only some offences within each group involve a measurable proprietary damage,

[3]The data used in this study was made available to us by the Bundeskriminalamt in machine-readable form.

Table 2: Risk and Per-Capita Property Loss

	All cases		Unsolved cases		Unsolved cases of theft	
State	Risk	p.c. loss	Risk	p.c. loss	Risk	p.c. loss
	p	$\bar{\ell}$ €	p	$\bar{\ell}$ €	p	$\bar{\ell}$ €
BW	0.0358	82.01	0.0174	19.33	0.0157	12.18
BAY	0.0295	76.70	0.0134	17.81	0.0119	9.11
B	0.0952	184.48	0.0611	79.70	0.0513	47.00
BB	0.0545	112.07	0.0282	36.39	0.0260	29.70
HB	0.1118	71.60	0.0725	38.38	0.0662	30.97
HH	0.1044	171.04	0.0684	63.15	0.0597	54.27
HE	0.0486	94.20	0.0290	37.81	0.0251	24.36
MVP	0.0696	95.72	0.0347	29.61	0.0314	24.20
NDS	0.0483	92.21	0.0266	22.81	0.0245	18.85
NRW	0.0577	118.62	0.0357	43.21	0.0322	31.64
RLP	0.0427	58.57	0.0214	22.23	0.0186	16.87
SL	0.0410	74.63	0.0224	26.70	0.0195	17.47
SN	0.0484	51.38	0.0236	17.06	0.0218	14.40
SNA	0.0572	66.58	0.0287	22.88	0.0264	18.96
SH	0.0573	119.88	0.0363	39.18	0.0333	22.58
TH	0.0409	41.06	0.0184	14.38	0.0165	11.19
GE	0.0500	97.77	0.0281	31.71	0.0252	22.14

Table notes. All data refer to 2004. Data source: Own calculations based on Bundeskriminalamt (2005).

that is then reported in the crime statistics: holdup murder (subgroup 0110); robbery, extortionate robbery, and robbery of motorists (2100); extortionate kidnapping (2330); hostage taking (2340); theft (complete groups 3 and 4); fraud (5100); defalcation (5200); embezzlement (5300); bankruptcy crimes (5600); extortion (6100); and certain economic crimes (7120, 7130, 7140, 7150). In order to compute p, we refer only to the offences in this list, except for those from group 7. Such crimes as, for instance, copyright and patent infringements, usually affect firms rather than private households.

For other offenses, such as murder and assault, one could try to find the respective monetary equivalents. For instance, in his very detailed study on the costs of crime in Germany, Spengler (2004) put forward an estimate of €1,65 million for the value of a statistical life (p. 106). He compared the wage markups of occupation groups that face different fatal-accident risks and a panel structure of the data in order to obtain his estimates. Without question the evaluation of health and life involves many problems and value judgements. On account of this, and because the efficiency conditions stated in Section 4 apply only to risks that can be fully underwritten, we restrict our attention to those offenses listed above, which involve a directly measurable proprietary damage. Of course, a full cost-benefit analysis of the police would have to take into account the whole spectrum of crime.

In column three, where we list the per-capita damage of all recorded cases, we implicitly assume that the associated loss of property persists even if a crime has been solved. In column five, we make the opposite assumption, that is, households get fully compensated for their loss after detection of the crime. Theft is reported separately, mainly for two reasons. First, theft in all its variations is a risk that can be fully underwritten. Second, in terms of case numbers, theft is the most important delict in the crime statistics and it has a relatively low detection rate. It contributes about 72 per cent of all cases in our list and about 89 per cent of all unsolved cases.

As can be seen in Table 2, the average risk of becoming a crime victim was about 5 per cent (within a period of one year). If we take into account only unsolved cases, it was 2.8 per cent. The probability of unsolved theft was 2.5 per cent. City-state Bremen (HB) was the leader in all three categories, while Bayern (BAY) was the safest place to live in.

As to the per-capita property loss, we note that the largest figures show up in Berlin (B) — a yearly damage of more than € 180 per capita. Referring to Germany as a whole, the per-capita damage was almost € 100. Multiplied by population, this gives as total proprietary damage of € 8 billion in 2004. Unsolved cases of theft caused a per-capita damage of about € 22 and a total damage of € 1.8 billion.

We do not want to withhold some limitations of our data. Many crimes do not get reported at all and, therefore, do not show up in the crime statistics. In some cases which have entered the crime statistics the actual loss of property could only be estimated; in other cases a symbolic value of one Euro was reported (and those cases cannot be separated from the rest). Furthermore, the probabilities listed in Table 2 are only an approximation of the "real" probability of an average person of becoming victim of a crime as some cases might have affected several people at the same time.

5.2 Estimating $p(G, n)$

Let $\mathcal{J} = \{1, \ldots, 16\}$ be the index set of states. We assume that the *functional form* of $p^i(\cdot)$ is identical for all people living in Germany and possesses a logistical distribution:

$$p^j = p(G_j, n_j) = \frac{1}{1 + \exp[-(\alpha + \beta G_j + \gamma n_j + \delta \frac{n_j}{A_j})]} \quad \forall j \in \mathcal{J} \,, \tag{21}$$

where $p_G \leq 0$ if $\beta < 0$ and $p_n > 0$ if $\gamma + \delta/A_j > 0$. The last term in the exponential function, $\delta n_j/A_j$, has been included to capture the effect of population density. α determines the basic probability of a loss at $p(0,0)$. Obviously, for $\alpha = 0$, we have $p(0,0) = 0.5$. For $\alpha \to \infty$ and $\alpha \to -\infty$, we observe $p(\cdot) = 1$ and $p(\cdot) = 0$, respectively. Multiplying (21) by $1-p$, taking the natural log and adding a disturbance term ε yields a well-known result, namely the logit model

$$L^j = \ln\left(\frac{p^j}{1-p^j}\right) = \alpha + \beta G_j + \gamma n_j + \delta n_j/A_j + \varepsilon_j \quad j \in \mathcal{J} \,, \tag{22}$$

which can easily be estimated (for grouped data) using weighted least squares with $\sqrt{n_j p^j (1-p^j)}$ as regression weights.[4]

Table 3: Logit-Model, ML-Estimates

		Risk scenario		
Variable	Coeff.	All cases	Unsolved cases	Unsolved cases of theft
Constant	$\hat{\alpha}$	-2.813	-3.460	-3.557
		0.001	0.002	0.002
Policemen (G)	$\hat{\beta}$	$-0.952E-4$	$-0.132E-3$	$-0.133E-3$
		$0.259E-6$	$0.157E-2$	$0.356E-6$
Population (n)	$\hat{\gamma}$	$0.226E-6$	$0.323E-6$	$0.327E-6$
		$0.638E-9$	$0.830E-9$	$0.878E-9$
Population (n/A)	$\hat{\delta}$	$0.546E-3$	$0.729E-3$	$0.713E-3$
density		$0.949E-6$	$0.123E-5$	$0.130E-5$
Log-likelihood		$-0.162E+8$	$-0.104E+8$	$-0.096E+8$
Pseudo R^2		0.931	0.963	0.967

Table notes. $n = 16$. First row: estimated coefficients, second row: standard errors. All estimates significant at the 1% level. Weighted by population.

[4]In contrast to this, Levitt (1997) used the change of crimes per capita as the endogenous and the change of the number of sworn police officers as the exogenous variable (both in logarithms), that is, he estimated the elasticity of crime rates with respect to the number of police officers.

Table 3 contains the results of estimating (22) for the three different risk scenarios considered. As noted above, we additionally included population density as a covariate. Other covariates, such as the per-capita BIP, the unemployment rate, and so on, could be included as well and would certainly have an influence on the exposure to crime. However, as our data is limited to 16 observations and the fit is already above 90%, we refrain from running more regressions.

All coefficients are significant at the 1 per-cent level and exhibit the expected sign. Hiring an additional policeman significantly decreases the probability of becoming a victim of crime, while population and population density increase the risk. Since it is difficult to interpret the size of the coefficients obtained from the logit model, we derive the respective marginal effects in the next subsection.

5.3 Marginal Effects

The marginal effects of G and n, respectively, on the probability of a loss can be computed as

$$\hat{p}^j_G = \hat{\beta}\frac{\exp[-(\hat{\alpha}+\hat{\beta}G_j+\hat{\gamma}n_j+\hat{\delta}\frac{n_j}{A_j})]}{\left\{1+\exp[-(\hat{\alpha}+\hat{\beta}G_j+\hat{\gamma}n_j+\hat{\delta}\frac{n_j}{A_j})]\right\}^2}\,, \tag{23}$$

$$\hat{p}^j_n = \left(\hat{\gamma}+\frac{\hat{\delta}}{A_j}\right)\frac{\exp[-(\hat{\alpha}+\hat{\beta}G_j+\hat{\gamma}n_j+\hat{\delta}\frac{n_j}{A_j})]}{\left\{1+\exp[-(\hat{\alpha}+\hat{\beta}G_j+\hat{\gamma}n_j+\hat{\delta}\frac{n_j}{A_j})]\right\}^2}\,. \tag{24}$$

The term in parentheses in equation (24) shows that population has a direct and an indirect crowding effect. First, rising population increases the number of people per police officer that have to be protected. Second, as population density increases, the basic likelihood of crime increases.

Starting from the efficiency condition for the optimum level of the public service (17), we derive a formula for the computation of the sum of the marginal benefits of the police. As all p^i's are identical, we have:

$$-\sum_{i\in\mathcal{I}^j} p^{i,j}_G(G_j,n_j)\ell_{i,j} = -p_G(G_j,n_j)\sum_{i\in\mathcal{I}^j}\ell_{i,j}\,. \tag{25}$$

Plugging the definition of the per-capita property loss

$$\bar{\ell}_j = \frac{\sum_{i\in\mathcal{I}^j}\ell_{i,j}}{n_j} \tag{26}$$

into (25) gives the sum of the marginal benefits of a policeman:

$$\Delta_G^j = -p_G(G_j, n_j)\bar{\ell}_j n_j \ . \tag{27}$$

In the same manner, we obtain an expression for the marginal costs of population:

$$\Delta_n^j = p_n(G_j, n_j)\bar{\ell}_j n_j \ . \tag{28}$$

Table 4: Marginal Benefits of Policemen and Marginal Costs of Population

State	Risk scenario: All cases	Risk scenario: Unsolved cases	Risk scenario: Unsolved cases of theft
	Δ_G^j € Δ_n^j €	Δ_G^j € Δ_n^j €	Δ_G^j € Δ_n^j €
BW	3.318.64	573.23	334.09
	8.41	1.49	0.87
BAY	2.904.17	457.93	216.91
	7.13	1.16	0.55
B	5.045.11	1.955.68	999.82
	44.42	16.90	8.47
BB	1.107.12	247.38	185.12
	2.84	0.65	0.49
HB	444.31	237.29	173.51
	7.36	3.82	2.73
HH	2.760.76	1.006.06	774.74
	27.52	9.82	7.40
HE	2.511.87	756.79	448.78
	6.65	2.05	1.22
MVP	708.18	157.12	117.83
	1.86	0.42	0.32

Table continues.

Table (4) presents the estimated marginal benefits of a policeman and the marginal costs of a citizen in terms of reduction/increase of statewide property losses due to crime. As can be taken from the table, there a huge differences between the states. To give an example, we focus on Bayern (BAY) and Hamburg (HH). Hiring an additional policeman would save Bavarian citizens roughly €2.900 per year. If we consider unsolved instances of theft

Continuation of Table 4

State	Risk scenario		
	All cases	Unsolved cases	Unsolved cases of theft
	Δ_G^j € Δ_n^j €	Δ_G^j € Δ_n^j €	Δ_G^j € Δ_n^j €
NDS	3.135.67 7.82	586.56 1.50	448.44 1.15
NRW	10.387.95 26.41	3.294.15 8.59	2.255.31 5.90
RLP	1.178.78 3.14	349.87 0.95	244.60 0.67
SL	456.26 2.10	132.57 0.61	79.46 0.36
SN	842.76 2.26	194.01 0.53	150.10 0.41
SNA	635.28 1.69	149.04 0.40	113.13 0.31
SH	1.707.87 4.68	435.42 1.22	230.97 0.65
TH	440.11 1.20	113.84 0.32	81.33 0.23

only, this figure melts down to €216. As compared to this, Hamburg would save €2.760 and €774, respectively. The fact that Hamburg's police are less successful in preventing and detecting theft than their Bavarian counterparts, combined with a much larger per-capita property loss, explains why the marginal return on an additional policeman is much higher in the city state.

If Bayern recruits a new citizen, this costs the original citizens a bit more than €7 per year. This property loss is due to the direct and indirect crowding effects explained above. As Hamburg already is a very crowded place, the effect is much greater: about €27.

5.4 Efficiency

Finally, we make an attempt to assess the efficiency of the provision of internal security in the German states. However, the results presented here should be taken with a lot of caution. In particular, we want to emphasize that our analysis is not to be seen as a recommendation to hire or release police officers somewhere. Necessarily, our treatment of the issue is too coarse and the data analysis depends on too many simplifying assumptions in order to admit such conclusions. The focus of our analysis is clearly on the local-public-good character of internal security, that is, on the returns-to-scale of population and on crowding effects. Table 4 shows that the benefits of an additional police officer are larger where many people live. At the same time, it indicates that negative crowding effects increase with increasing population and, in particular, population density.

Of course, a complete cost-benefit analysis of the police requires assumptions about the cost structure. This means that we have to substantiate the right hand side of equations (17) and (20). We assume that the total cost of the police is proportional to the number of police officers:

$$C^j = C(G^j) = \eta G_j \quad \forall\, j \in \mathcal{J} \ , \tag{29}$$

where $\eta > 0$ is the marginal costs of a policeman. The police are financed by uniform head taxes:

$$c^{i,j} = c(G_j, n_j) = \frac{C^j}{n_j} = \frac{\eta G_j}{n_j} \quad \forall\, i \in \mathcal{I},\ j \in \mathcal{J} \ . \tag{30}$$

Hence, (for sufficiently large n) the marginal return on an additional citizen for an original citizen is given by

$$c_n^{i,j} = -\frac{\eta G_j}{(n_j)^2} \ . \tag{31}$$

Equation (31) shows that the decrease of the individual contributions to the public service shrinks with increasing population as total costs are borne by more and more citizens. The statewide return is

$$\sum_{i \in \mathcal{I}^j} c_n^{i,j}(G_j, n_j) = n c_n^j(G_j, n_j) = -\frac{\eta G_j}{n_j} \ . \tag{32}$$

Using the assumptions made in the previous subsections and the cost function (29), we obtain a simplified Samuelson condition

$$\Delta_G^j = \eta \ , \tag{33}$$

and a simplified membership condition:

$$\Delta_n^j = \frac{\eta G_j}{n_j} \ . \tag{34}$$

Solving these two equations for G and n yields the optimum level of internal security in terms of police officers

$$G_j^\star = \eta \frac{[1+\exp(-\alpha)]^2}{\exp(-\alpha)} \frac{\left(\gamma + \frac{\delta}{A_j}\right)}{\beta^2 \bar{\ell}_j} , \tag{35}$$

and the optimum population

$$n_j^\star = -\eta \frac{[1+\exp(-\alpha)]^2}{\exp(-\alpha)} \frac{1}{\beta \bar{\ell}_j} . \tag{36}$$

Obviously, the optimum number of police officers is proportional to the optimum population.

Dividing $G^\star$ by $n^\star$ yields the optimum number of police officers per capita:

$$g_j^\star = \frac{G_j^\star}{n_j^\star} = \frac{\left(\hat{\gamma} + \frac{\hat{\delta}}{A_j}\right)}{-\hat{\beta}} . \tag{37}$$

This ratio decreases with increasing absolute value of $\hat{\beta}$ (remember that $\hat{\beta} < 0$). A larger $|\hat{\beta}|$ means that police officers become more effective in reducing crime risks. Hence, local authorities have to spend less funds on internal security. The numerator specifies the direct and indirect crowding effect onto the optimum number of police officers per capita: the more crowding feeds and facilitates crime, the more police is needed.

In order to obtain values for the optimum number of police officers and the optimum population, we would first have to estimate the marginal cost of a policeman η, or to take the value from an official statistics. The respective value could then be plugged into equations (35) and (36). In our case, where we take into account only crimes that involve a property loss, such a proceeding would be misleading. We would dramatically overestimate the marginal cost of an additional police officer. Hence, we present our efficiency analysis in terms of the optimum number of police officers per capita.

For a hypothetical German average state with an area of $22,314\ km^2$ (see Table 1) and a per-capita loss of €97.77 (see Table 2), we obtain the following expressions for population:

$$\bar{n}^\star \approx 2011 \times \eta , \tag{38}$$

and number of police officers:

$$\bar{G}^\star \approx 5.2915 \times \eta , \tag{39}$$

if we take into account all instances of crime (see Table 3 for parameters). Accordingly, the number of police officers per 1000 citizens is given by

$$\bar{g}^{\star}(\times 1000) \approx 2.63\ . \tag{40}$$

Comparing this number with the actual number of police officers per 1000 citizens, which is 3.18 (see Table 1), shows that according to this measure, the number of police officers is relatively high.

Table 5: Actual and Optimum Number of Policemen per 1000 Citizens

		Optimum		
State	Actual	All cases	Unsolved cases	Unsolved cases of theft
BW	2.86	2.53	2.60	2.60
BAY	2.92	2.45	2.52	2.53
B	7.12	8.80	8.63	8.46
BB	3.84	2.56	2.63	2.64
HB	5.03	16.57	16.11	15.72
HH	5.60	9.97	9.76	9.55
HE	2.93	2.64	2.70	2.71
MVP	3.80	2.62	2.68	2.68
NDS	2.75	2.49	2.56	2.57
NRW	2.57	2.54	2.60	2.61
RLP	2.73	2.66	2.72	2.72
SL	3.20	4.60	4.59	4.54
SN	3.47	2.68	2.74	2.74
SNA	4.02	2.65	2.71	2.72
SH	2.77	2.73	2.79	2.79
TH	3.31	2.72	2.78	2.79
${\varepsilon_{G,n}}^{a}$	0.626	0.626	0.627	0.627

Table note. [a]Elasticity of the number of police officers with respect to population.

Table 5 lists the actual number of police officers per 1000 citizens for each German state and, as before, the optimum values for all cases, only unsolved instances of crime, and unsolved theft. As can be taken from the table, Germany's capital Berlin (B) exhibits the highest per-capita level of police protection, about 7 police officers per 1000 citizens. Still, our theoretical and empirical analysis suggests that this number is too low. Germany's largest state both in terms of area and population, Nordrhein-Westfalen (NRW) affords about 2.5 police officers per 1000 citizens. Though this value is much smaller than Berlin's, it seems to be in the optimum range. The difference between Berlin and NRW is, of course, due to the lower level of congestion in NRW. In Bayern (BAY), the level of internal security is a bit too high, while Hamburg (HH) does not spend enough on the police (in per capita terms).

Another interesting case is Bremen (HB), which is Germany's smallest state. The downtown of Bremen takes only 404 km^2 (see Table 1). Hence, returns to scale are at a very low level, and a relatively high per-capita endowment with police officers is required. In order to clarify this point, we compute the optimum population according to formula (36), which gives $2,746 \times \eta$. Assuming that the actual population of Bremen is the optimum population, gives $\eta = 241$. For $G^\star$ we have according to equation (35) $45.51 \times \eta = 10,989$. The actual number of police officers in Bremen is, however, only $3,342$, that is, more than three times smaller.

Define $\varepsilon_{G,n} = G_n/g$ as the elasticity of the (optimum) number of police officers with respect to population, in short, the so-called population elasticity. Note that this definition of the population elasticity does not depend on the metrization of the public good in the utility function (compare Reiter and Weichenrieder, 1999). Running simple OLS regression (through the origin) with the logarithms of the actual and the optimum number of police officers (G_j is taken from Table 1, $G_j^\star$ is given by $g_j^\star \times n_j$ taken from Tables 1 and 5) as the endogenous variable and the logarithm of population as the exogenous variable yields the figures reported at the bottom of Table 5. Irrespective of whether we consider the actual or the optimum numbers, the population elasticity is a bit greater than 0.62.[5]

As Reiter and Weichenrieder (1999) have shown, the estimates of the population elasticity obtained from different empirical studies cannot be compared easily if different metrizations of the public good or different measurement units have been chosen. Using Bewley's (1981) terminology, $\varepsilon_{G,n} = 1$ would mean that internal security is a pure public service, while $\varepsilon_{G,n} = 0$ would mean that internal security is a pure public good. Hence, our estimates suggest that the police exhibits a significant degree of publicness. This result contradicts most other empirical studies (see Table 1 in Reiter and Weichenrieder, 1997).

[5]We do not report the full estimation results here in order to save space. 95% confidence intervals indicate that the $\varepsilon_{G,n}$'s are larger than 0.6 and smaller than 0.65. Note that the $g_j^\star$'s themselves are stochastic quantities.

6 Conclusions

In a recent paper, Lohse et al. (2005) broadened the topology of public goods by those which reduce the risk and/or the extent of proprietary losses. While Lohse et al. focussed only on pure public goods, we derive efficiency conditions for local public services the benefits of which are spatially limited and subject to crowding. The respective Samuelson condition states that the optimum level of the public service is reached where the sum of the marginal benefits in terms of reduction of expected property losses equates the marginal costs of the service. According to the membership condition, the sum of the marginal crowding effects caused by an additional citizen in terms of increased risk of a property loss must meet the decrease in the original citizen's contribution to the public service.

In our empirical application, we present an efficiency analysis of the provision of internal security in Germany. Our data refers to the state level. Since the efficiency conditions presented in this paper depend on the assumption that proprietary risks can be fully underwritten, we only consider offenses which involve a measurable loss of property. Estimates for the marginal benefits of an additional police officer and for the marginal costs of an additional police officers are derived. The efficiency of the provision of the police is then assessed with respect to the optimum number of police officers per citizen. Our data suggests that there are strong returns-to-scale in the provision of internal security as small states require many more police officers per capita than larger ones.

Levitt (1997) found that in the US the social benefit of reduced crime was about \$ 100,000 per officer per year and, therefore, concluded that the current number of police was below the optimal level. With regard to our study, such conclusions would be inadequate as we restricted our attention to offenses involving property damage. However, the analysis of actual and optimum per-capita endowments of the German länder with police officers warrants some cautious policy recommendations. First, due to strong crowding externalities the city states, Berlin (B), Bremen (HB) and Hamburg (HH), require more police officers in per-capita terms although their actual endowments are already relatively high. Second, the former East German states, Brandenburg (BB), Mecklenburg-Vorpommern (MVP), Sachsen (SN), Sachsen-Anhalt (SNA) and Thürigen (TH) are sparsely populated and therefore need less police officers than they currently have. Third, due to returns-to-scale in the provision of internal security, large states need less police officers in per-capita terms than small units. Our data suggests that in the smaller states, population is not at the optimum level. Hence, one could rethink the present structure of the German länder. Indeed, there is an ongoing discussion in

Germany about amalgamating some of the smaller states.

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