Krause, Günter

Working Paper

On the role of budgeting in the delegated provision of public goods under asymmetric information

Würzburg economic papers, No. 51

Provided in cooperation with:
Julius-Maximilians-Universität Würzburg

W. E. P.

Würzburg Economic Papers

No. 51

On the role of budgeting in the delegated provision of public goods under asymmetric information

Günter Krause

August 2004

Universität Würzburg
Lehrstuhl VWL 2
Sanderring 2, D-97070 Würzburg
guenter.krause@mail.uni-wuerzburg.de

Postal Address
Günter Krause
Universität Würzburg
VWL 2
Sanderring 2/IV
D-97070 Würzburg
Germany

Bachstrasse 8
D-99867 Gotha
Germany
guenter.krause@mail.uni-wuerzburg.de

On the role of budgeting in the delegated provision of public goods under asymmetric information

Guenter Krause

University of Wuerzburg

Abstract:

The present paper investigates the neglected topic of budgeting rules for public bureaucracies performing governmental activities within predetermined budgets under rules governing expenditure levels and composition. We analyze the optimal budgeting scheme, if the bureaucracy has superior information vis à vis the policymaker. It is tasked with supplying different types of public goods and is subject to costly audits. The optimal budgeting scheme for the bureaucracy is determined. It is shown that it crucially depends on the level of auditing costs. The same holds for the extent of discretion given to the bureaucracy about levels and composition of public expenditures.

JEL classification: H41, H61

1. Introduction

Traditionally, analysis of the provision of public goods has concentrated on – (1) the implications of different tax policy instruments on provision rules under symmetric information between public and private entities (Samuelson rules); (2) mechanisms to extract consumer preferences under asymmetric information between them; and (3) whether voluntary provision of public goods can survive the free-rider problem. Recent studies have focused on the impact on the optimal supply of public goods, if there is asymmetric information between different public sector entities. The present paper looks at the neglected topic of budgeting rules especially those of public bureaucracies performing government activities within predetermined budgets under rules governing both expenditure levels and composition. We analyze the optimal budgeting scheme, if the bureaucracy has superior information vis à vis the policymaker. It is tasked with supplying different types of public goods and is subject to costly audits. The optimal budgeting scheme for the bureaucracy is determined. It is shown that it crucially depends on the level of auditing costs. The same holds for the extent of discretion given to the bureaucracy about both levels and composition of public expenditures.

Behavior of public bureaucrats traditionally has been analyzed according to the basic model of Niskanen (1971) where bureaucrats try to maximize the budgets under their control, using their procedural advantages in the process of determining policy decisions. This perspective has been augmented by the Leviathan perspective of Brennan/Buchanan (1980) who start from the presumption that the public agents are not only primarily interested in their own welfare, but that their individual welfare or utility measure is focused on using the resources at their disposal for their private gain and not for the public purpose for which it was entrusted to them. This differs from the original Niskanen perspective insofar as there the bureaucrats are interested in receiving a bigger budget because this raises their individual utility. In the Leviathan perspective the public decision makers are not necessarily interested in receiving a bigger budget but in being able to spend a bigger amount of any resources at their disposal on activities which raise only their individual utilities and not the welfare of the general public. Whether they get a larger amount out of a bigger or smaller budget is not important in this respect. Some recent contributions employing the Leviathan perspective to analyze government behavior and institutional regulations in federations are summarized in Wrede (2001).

Gordon/Wilson (1999, 2001) and Wilson (2000) have taken a related approach. They model public decision makers who are able to use parts of the public funds under their disposal and over which they have discretionary spending authority for their private benefit to the detriment of the public, i.e. in a welfare reducing way. To control and regulate this behavior the public can use different institutional arrangements of the tax system. In Gordon/Wilson (1999) and in Wilson (2000), the tax system is structured in such a way that the deciding public agent is induced to act at least in part in the public interest to further his own. If the tax system using consumption and income taxes is structured in such a way that it takes into account that public officials have different preferences over the mix of public goods than the general public or the median voter, their expenditure decisions can be influenced in a welfare improving way. Wilson (2000) reaches a similar conclusion in the design of a tax system, where the public official has to provide public production goods in order to generate any tax revenue which can be appropriated for his private benefit. Taking into account the elasticity of different factor tax bases to the expenditure decisions leads to the conclusion that tax competition can be welfare improving as public officials in different regions are forced to provide more public services in order to increase their discretionary consumption on the job. This is related to the old analysis of Williamson (1967) who analyzed the behavior of private managers who have the ability to consume on the job, i.e. to waste their shareholders capital and who can be forced by competition to reduce this waste.

These approaches do not explicitly model the asymmetric distribution of relevant information between the public decision maker and the political supervisors.

Another recent line of analysis, especially Boadway/Horiba/Jha (1998) and Boadway/Marceau/Sato (1999) have explicitly analyzed asymmetric information between public agents to derive results concerning the institutional organization of government and the optimal tax system to finance governmental activities.

Boadway/Horiba/Jha (1998) use the principal-agent paradigm to analyze methods to influence the effort decisions of public agents who are able to reduce the costs of providing public goods which are financed using distortionary labor taxation. They derive a system of optimal grants to agencies tasked with the actual provision of the public goods and who may exert effort to reduce the costs of provision. Agencies correspondingly receive informational rents as quasi-profits which raise the utility of the agency decision makers.

Boadway/Marceau/Sato (1999) discuss the optimal organization of a social welfare system where many public agents are tasked with expending effort to identify and separate intended recipients of social aid from those who are unwilling to work. Social workers are paid on a case by case schedule such that they are equivalent to result dependent agents known from principal agent theory. The optimal incentive schemes are derived and it is shown that the optimal pay structure rewards the social workers for effort. This implies that public sector workers should be paid more on a result dependent schedule and less on a fixed salary bases. A conclusion Williamson (1999) shares for workers in many government activities.

In the theory of corporate finance, Harris/Raviv (1998, 1996) in series of contributions have analyzed budgeting rules under asymmetric information between different economic agents. Abstracting from effort decisions they analyze inherent informational advantages that agents may have vis a vis their principals. They demonstrate that budgeting may be used to implement information revelation mechanisms that enable principals to take advantage of information their agents receive to improve their utility.

The present paper intends to demonstrate that this approach from the theory of corporate finance provides a useful way to analyze budgeting rules and regulations in the public sector where the focus is not in the level of investment but on determining the optimal amount of different public goods to be provided on behalf of private agents. The public bureaucracy is thus not viewed as a quasi-firm whose purpose it is to produce public goods. The primary role of the bureaucracy, or, more specifically in the following, the agent heading the bureaucracy or agency, is the collection of information which can be used to improve public decisions, which are relevant for the welfare of citizens.

The paper is organized as follows: section 2 presents the model for the provision of two public goods by an agency which is in possession of private information about the realised intensity of preferences for two types of public goods. Section 3 derives the optimal solution for the structure with public goods and discusses the differences in the modeling structures compared to Harris/Raviv (1998). It also relates how the theoretical revelation mechanism can be transformed into a mechanism that is familiar not only from corporate finance but that also resembles structures and procedures known from public policy. A short summary in section 4 concludes.

2. The structure of the model

The following structure is based in part on the model of Harris/Raviv (1998). It is, however, necessary to take into account differences in the structure of the model, because a utility based welfare analytic approach is not completely equivalent to the analysis of different investment projects in a private firm.

The private sector

We consider a jurisdiction, which is inhabited by a representative household. Preferences are given by the following quasi-linear utility function

$$u = x + \theta_1 v(g_1) + \theta_2 v(g_2), \tag{1}$$

where x denotes a representative private consumption good and g_i, $i = 1, 2,$ are local public goods to be provided by the local agency charged by the government with that task. In the following analysis, the amount of the public goods will play a vital role, because of the preferences of a public decision maker. Therefore we will use "size of the public facilities" synonymously with public goods. The $v(g_i)$ are strictly concave elementary preference functions that capture the utility the household receives from the public goods. θ_i, $i = 1, 2,$ are parameters that denote the intensity of the preferences for the respective local public good. Both parameters can attain either a high or a low value: $\theta_i \in \{\theta^L, \theta^H\}$, $i = 1, 2$. The elementary preference functions $v(g_i)$ are identical such that differences in the importance of the two public goods are solely captured by the intensity parameters θ.

The introduction of the type parameter in multiplicative form is used, because this is a typical approach in the economics of information and also because it reduces notational effort. In the present case, however, it has also an impact on the applicability of results. It influences the range of elementary utility functions for which the results hold.[1]

[1] See assumption A2 below.

The endowment of the representative household is denoted by Y. It can be used to purchase the consumption good, which serves as a numeraire good and the price of which is normalized to unity. The other way the household "uses" its endowment is to pay taxes T, which cover the production costs for the public goods such that the budget of the government reads

$$T = c(g_1, g_2) + q$$

q denotes possible auditing costs that the government can incur to determine whether information provided by its agent has been the truth. $c(g_1, g_2)$ denotes a general cost function more about which will be specified in due course.

Under these assumptions, the indirect utility function of the household, U, depending on the instruments of the government is given by

$$U = Y - c(g_1, g_2) - q + \theta_1 v(g_1) + \theta_2 v(g_2). \quad (2)$$

The amount of the public goods and hence the final utility of the household will depend on the values of the intensity parameters θ. From the viewpoint of the government this creates a problem akin to one under uncertainty whereas the household acts under certainty. This formulation also incorporates a key difference in our approach compared to e.g. Boadway/Horiba/Jha (1999). The information rent captured by the agency will not be used for private consumption of the agency decision maker, but will be incorporated into larger public facilities being build than would be warranted given realized preferences.

The public sector

The public sector is comprised of the government which wants to maximize the utility of the representative household and an agency which is tasked with providing the two local public goods.

The agency

The two local public goods are provided by a local agency headed by a decision maker. In contrast to Boadway/Horiba/Jha (1999), this public "manager" is not tasked with exerting effort to reduce the cost of providing a single public good. Instead his task is to discover the respective preference intensities of the household for the two types of public good.

Two methods often-analysed to extract this kind of information are voting mechanisms and the pivot mechanism of Groves/Ledyard (1977). Both of these approaches suffer from a lack of realism and empirical relevance. Public bureaucracies often have to take decisions concerning local public goods during the mandated terms of elected public bodies without holding referenda or special elections to elicit private information from consumer-households over their preferences over different alternatives. Neither do they use Groves-Clark-Vickrey mechanisms in practice to gather information relevant to their decisions.

One interpretation of the role of public bureaucracies is that one of their main tasks is the collection of information about private sector activities which are relevant for public decisions or public policy making without recourse to the mechanisms typically analysed in theoretical papers.

One recent contribution analysing the information gathering role of public employees is Boadway/Marceau/Sato (1999) who discuss social workers as information gathering agents that collect information about work capabilities of potential welfare recipients. They analyse the effort decision of these workers. Effort has to be exerted in order to get better information about applicants for welfare payments. The effort decision is influenced by subsequent, publicly and without cost observable decisions of the household, namely whether they take up work or not after being denied welfare. Depending on the type of welfare payment employed this can give additional valuable information about the effort the social workers have actually invested in making accurate decisions about the "need" of the applicants. One important problem in terms of realism of their analysis is that the wage schedule used for social workers makes their pay dependant on outcome, which is rarely observed in reality where most civil servants and public employees get fixed salaries not depending on their actual performance on the job or on measures of this performance. This property of actual public pay schedules is also evidenced and studied in the recent contributions by Tirole (1994) and Dewatripont/Jewitt/Tirole (1999).

Kommentar: Seite: 8
This oppens up a further modificationof the boadway paper by critizising this approach. The black market economy exists precisely because talking up work is not costlessly observable by public agents in the broadest sense of the term.

To analyse the pure information problem we will assume that the decisions maker (head of the public agency) receives information about the intensity of the preferences costless and perfectly. He then transmits a message to the government about the state of the world. This message may be truthful or a misrepresentation. The government has to perform an audit (in practice employ a different agent) if it wants to know for sure whether it was told the truth in this message or whether it was lied to.[2] The agency then receives a budget from the government to provide the two local public goods. The budget may contain mandates on how the money must be spent. The agency does not have the Leviathan-ability to use parts of this budget for different purposes.

A similar interpretation of the situation would be a division of responsibilities between a taxing ministry and spending ministries within the government, with the first being responsible for collecting tax revenues and different spending ministries being responsible for individual portfolios of tasks.[3]

The objective of the agency head, whom we also call the decision maker, is to maximise the aggregate level of public goods. The only way to do this, lacking any other instrument, is to use his informational advantage vis-à-vis the government for that purpose. The conflict of interest between the agency and government can therefore be captured by the following objective function for the agency

$$u^a = b(\theta_1) g_1 + b(\theta_2) g_2 . \qquad (3)$$

This preference function captures the similarity between the objectives of the agency and the government, but it also allows for a conflict of interest as both the weights and the functional forms differ from the ones exhibited by the representative household.

[2] Laffont (2000) gives a survey of approaches that analyse in detail the possibilities of collusion between different agents against the principal. These are evolutionary models in the sense that they apply knowledge gained in the theory of optimal regulation is applied to other contexts in economic analysis.

[3] Compare Besley/Jewitt (1991), Boes (1991), Boes (2000).

When necessary we simplify (3) further to[4]

$$u^a = \theta_1 g_1 + \theta_2 g_2 . \qquad (4)$$

One motivation, related to a Niskanen (1971)-type of analysis, for these preferences is that the head of the agency is concerned only with the size of the public facilities, to gain public prestige as a surrogate for higher monetary compensation. Examples of public facilities being too large as envisioned by public officials easily come to mind.[5]

These preferences imply that the agency is risk neutral with respect to the levels of public goods sanctioned by the government. The penalty for the head of the agency consists in loosing his job and being relegated to his reservation utility if an audit reveals that he misrepresented the true state of the world in his message to the government.

The government

The government designs a mechanism to elicit information from the agency and then proceeds to tax the citizen and produce the public goods in accord with the information about preferences of the public goods obtained from the agency.[6] This mechanism consists of levels of public goods to be provided given the information send by the agency and audit probabilities, which determine whether an audit will be performed by the government. This approach makes it unnecessary to analyze the treatment of an agency profit within the model (as in Boadway/Horiba/Jha (1999)[7]), because transferred funds will always be used for production of public goods. The private benefit of the agency (or more precisely the decision maker of the agency who makes the relevant decisions) consists of a higher utility, if he manages to get the government to approve more public goods than would be called for given the true realized state of the world. This implies that the present paper analyses in more

[4] We could also assume that it had the same gross evaluation as the consumer but did just not care for costs. One reason for such a preference could be that the agency would not be held liable by the consumer for the costs incurred in supplying him with the public goods but could be able to shift the public blame to the government/taxing ministry.

[5] Many German cities today are burdened with public facilities that are too large compared to what would have been considered optimal, especially in the areas of waste water treatment and waste disposal. Examples can easily be found in accounts in the German media.

The problem is also not confined to Germany. E.G., in the city of East Lansing, MI, school board officials wanted larger swimming facilities compared to those that the citizens finally choose. If the decisions are not based on voting as in such a case, e.g. in administrative agencies of larger governments, there is no reason to assume that this kind of behavior will not be observed**.** The motivation of the paper is to analyze how budgetary rules and methods can contain such wasteful behavior of public officials. As all governments world wide rely to a large extend on budgetary rules to constrain expenditures and not on result dependent (contingent) pay schedules as prescribed by standard agency theoretic models, this seems well warranted for such an initial analysis.

[6] This analysis is similar to the situation Gordon/Wilson (2003) where the decision maker has the authority to determine the mix of public goods to be produced. The traditional reasoning from fiscal federalism to have more than one government authority involved if there is more than one good (to elicit information about preferences) is consonant with this.

[7] They, however, also fail to consider the consequences how an agency profit might influence the equivalency of available government tax instruments in their model.

detail the process, first studied by Niskanen (1971), how public officials manage to enlarge their budgets beyond socially optimal levels.

As usual in this kind of analysis, it is assumed that the government is committed to implement the probabilities implied by the mechanism although it does know that the truth will be told given those probabilities. Thus we abstract from the problem of time-consistency in government decision making.

As an element of the mechanism, the government may, although at a cost, audit the agency and determine whether the report was true.[8] If the agency is found to be lying, i.e. the decision maker is caught sending a report which overstates his case, the government can replace and punish the decision maker in a way that he no longer benefits from the decisions the government takes in that situation.[9] Examples could be the disgrace and fall from public reverence that public officials often face when they are caught "red-handed". Also their contribution in the initial phase is easily forgotten if they are not present at the final stage of the completion of the respective projects. Given that a large part of the remuneration in the public sector is career based and hence pushed into later parts of the work life of a public employee[10] such a loss of public reputation can be seen as the equivalent to the modeled effect on the utility of the decision maker.

Let the state of the world be $\alpha = (ij) = \{\theta_1^i, \theta_2^j\}, i, j = L, H$. The four possible states of the world can be abbreviated by $\alpha \in \{(LL),(LH),(HL),(HH)\}$. The probability of state α occurring is $\pi(\alpha)$, with $\sum_\alpha \pi(\alpha) = 1$. The probability preset (and pre-committed to) by the government to conduct an audit of the agency which will make the private information obtained about the preference intensities public is denoted by $\gamma(\alpha)$. The audit cost incurred is denoted by q.

The cost of producing the public goods is $C(g_1, g_2) = c(g_1) + c(g_2)$.[11]

The objective function of the government is

[8] The auditing approach is also taken e.g. in Cremer/Gahvari (2000), Cremer/Marchand/Pestieau (1996).

[9] The same assumption is employed by Gordon/Wilson (1999, 2003) in their papers on public officials who may loose their jobs if they do not supply to their residents the necessary utility compared to alternate jurisdictions.

[10] Cf. recent contributions by Dewaripont/Jewitt/Tirole (1999) but also the classic study by Becker/Stigler (1974). This approach was carried to an extreme in ancient Egypt, where removal of inscriptions from public sites could extend punishment even into the afterlife of the affected public official.

[11] It is necessary to be able to apply the general results of Harris and Raviv (1998) that the cost function has a certain degree of convexity. This implies that the standard assumption of a uniform and linear rate of transformation between public and private goods precludes the analysis of informational problems in the present context. If necessary we will employ the following cost function which exhibits the necessary convexity: $c(g) = g^3$. See the discussion below in section 3.

$$
\begin{aligned}
EU = \pi(LL) & \begin{Bmatrix} (1-\gamma(LL))\left\{Y+\theta_1^L v\left(g_{1N}^{LL}\right)+\theta_2^L v\left(g_{2N}^{LL}\right)-c\left(g_{1N}^{LL}\right)-c\left(g_{2N}^{LL}\right)\right\} \\ +\gamma(LL)\left\{Y+\theta_1^L v\left(g_{1A}^{LL}\right)+\theta_2^L v\left(g_{2A}^{LL}\right)-c\left(g_{1A}^{LL}\right)-c\left(g_{2A}^{LL}\right)-q\right\} \end{Bmatrix} \\
+\pi(LH) & \begin{Bmatrix} (1-\gamma(LH))\left\{Y+\theta_1^L v\left(g_{1N}^{LH}\right)+\theta_2^H v\left(g_{2N}^{LH}\right)-c\left(g_{1N}^{LH}\right)-c\left(g_{2N}^{LH}\right)\right\} \\ +\gamma(LH)\left\{Y+\theta_1^L v\left(g_{1A}^{LH}\right)+\theta_2^H v\left(g_{2A}^{LH}\right)-c\left(g_{1A}^{LH}\right)-c\left(g_{2A}^{LH}\right)-q\right\} \end{Bmatrix} \\
+\pi(HL) & \begin{Bmatrix} (1-\gamma(HL))\left\{Y+\theta_1^H v\left(g_{1N}^{HL}\right)+\theta_2^L v\left(g_{2N}^{HL}\right)-c\left(g_{1N}^{HL}\right)-c\left(g_{2N}^{HL}\right)\right\} \\ +\gamma(HL)\left\{Y+\theta_1^H v\left(g_{1A}^{HL}\right)+\theta_2^L v\left(g_{2A}^{HL}\right)-c\left(g_{1A}^{HL}\right)-c\left(g_{2A}^{HL}\right)-q\right\} \end{Bmatrix} \\
+\pi(HH) & \begin{Bmatrix} (1-\gamma(HH))\left\{Y+\theta_1^H v\left(g_{1N}^{HH}\right)+\theta_2^H v\left(g_{2N}^{HH}\right)-c\left(g_{1N}^{HH}\right)-c\left(g_{2N}^{HH}\right)\right\} \\ +\gamma(HH)\left\{Y+\theta_1^H v\left(g_{1A}^{HH}\right)+\theta_2^H v\left(g_{2A}^{HH}\right)-c\left(g_{1A}^{HH}\right)-c\left(g_{2A}^{HH}\right)-q\right\} \end{Bmatrix}
\end{aligned} \tag{5}
$$

where the subscript N or A denotes allocations of goods in states of the world where the government audits the agency (A) or does not (N). This objective function implies that the government is maximizing the expected utility of the private sector / the representative citizen. It is a benevolent government in the traditional vein of analysis.

Written out in full the incentive compatibility constraints for the different types of agency (in the 4 possible states of the world), which are added to the objective function to get the Lagrangian, are

for state/type LL

$$
\begin{aligned}
&+\mu_{LL,LH} \begin{Bmatrix} (1-\gamma(LL))\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\gamma(LL)\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right) \\ -(1-\gamma(LH))\left(b(L)g_{1N}^{LH}+b(L)g_{2N}^{LH}\right) \end{Bmatrix} \\
&+\mu_{LL,HL} \begin{Bmatrix} (1-\gamma(LL))\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\gamma(LL)\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right) \\ -(1-\gamma(HL))\left(b(L)g_{1N}^{HL}+b(L)g_{2N}^{HL}\right) \end{Bmatrix} \\
&+\mu_{LL,HH} \begin{Bmatrix} (1-\gamma(LL))\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\gamma(LL)\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right) \\ -(1-\gamma(HH))\left(b(L)g_{1N}^{HH}+b(L)g_{2N}^{HH}\right) \end{Bmatrix}
\end{aligned} \tag{6}
$$

the first part of the incentive compatibility constraint shows that the utility for the decision maker must be higher if he tells the truth than if he misrepresents his information and pretends that the realized state of the world is (LH). He can enjoy the possible higher utility of a bigger budget through misrepresentation only, if he is not audited when announcing (LH). Hence if he is caught misrepresenting his information, his utility will be his reservation utility after being removed from office, which is normalized to zero. Therefore only variables with the $N-$subscript are subtracted from the utility under truth-telling.

Accordingly, the constraint for state/type LH reads

$$+\mu_{LH,LL}\begin{Bmatrix}(1-\gamma(LH))\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\gamma(LH)\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\\-(1-\gamma(LL))\left(b(L)g_{1N}^{LL}+b(H)g_{2N}^{LL}\right)\end{Bmatrix}$$

$$+\mu_{LH,HL}\begin{Bmatrix}(1-\gamma(LH))\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\gamma(LH)\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\\-(1-\gamma(HL))\left(b(L)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)\end{Bmatrix} \qquad (7)$$

$$+\mu_{LH,HH}\begin{Bmatrix}(1-\gamma(LH))\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\gamma(LH)\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\\-(1-\gamma(HH))\left(b(L)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)\end{Bmatrix}$$

, for state/type HL

$$+\mu_{HL,LL}\begin{Bmatrix}(1-\gamma(HL))\left(b(H)g_{1N}^{HL}+b(L)g_{2N}^{HL}\right)+\gamma(HL)\left(b(H)g_{1A}^{HL}+b(L)g_{2A}^{HL}\right)\\-(1-\gamma(LL))\left(b(H)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)\end{Bmatrix}$$

$$+\mu_{HL,LH}\begin{Bmatrix}(1-\gamma(HL))\left(b(H)g_{1N}^{HL}+b(L)g_{2N}^{HL}\right)+\gamma(HL)\left(b(H)g_{1A}^{HL}+b(L)g_{2A}^{HL}\right)\\-(1-\gamma(HL))\left(b(H)g_{1N}^{LH}+b(L)g_{2N}^{LH}\right)\end{Bmatrix} \qquad (8)$$

$$+\mu_{HL,HH}\begin{Bmatrix}(1-\gamma(HL))\left(b(H)g_{1N}^{HL}+b(L)g_{2N}^{HL}\right)+\gamma(HL)\left(b(H)g_{1A}^{HL}+b(L)g_{2A}^{HL}\right)\\-(1-\gamma(HH))\left(b(H)g_{1N}^{HH}+b(L)g_{2N}^{HH}\right)\end{Bmatrix}$$

and finally for state/type HH

$$+\mu_{HH,LL}\begin{Bmatrix}(1-\gamma(HH))\left(b(H)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\gamma(HH)\left(b(H)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\\-(1-\gamma(LL))\left(b(H)g_{1N}^{LL}+b(H)g_{2N}^{LL}\right)\end{Bmatrix}$$

$$+\mu_{HH,LH}\begin{Bmatrix}(1-\gamma(HH))\left(b(H)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\gamma(HH)\left(b(H)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\\-(1-\gamma(LH))\left(b(H)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)\end{Bmatrix} \qquad (9)$$

$$+\mu_{HH,HL}\begin{Bmatrix}(1-\gamma(HH))\left(b(H)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\gamma(HH)\left(b(H)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\\-(1-\gamma(HL))\left(b(H)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)\end{Bmatrix}$$

In many aspects this model has a structure which is related to Harris/Raviv (1998) and therefore their conclusions concerning the optimal solution to the problem of a firm organized into divisions setting budgets for a well-informed divisional manager are applicable.

3. Analysis

As a case of reference we first derive the solution to the problem of the government if there are no informational problems. In the present setting this amounts just to maximizing expected utility (5) without any of the incentive compatibility constraints (6)-(9).

In this standard problem, the first order conditions for the respective amounts of public goods if there are no audits read as

$$\frac{\partial EU}{\partial g_{1N}^{LL}} = \pi(LL)\left(1-\gamma(LL)\right)\left(\theta_1^L v'\left(g_{1N}^{LL}\right) - c'\left(g_{1N}^{LL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1N}^{LL}} = \pi(LL)\left(1-\gamma(LL)\right)\left(\theta_2^L v'\left(g_{2N}^{LL}\right) - c'\left(g_{2N}^{LL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1N}^{LH}} = \pi(LH)\left(1-\gamma(LH)\right)\left(\theta_1^L v'\left(g_{1N}^{LH}\right) - c'\left(g_{1N}^{LH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2N}^{LH}} = \pi(LH)\left(1-\gamma(LH)\right)\left(\theta_2^H v'\left(g_{2N}^{LH}\right) - c'\left(g_{2N}^{LH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1N}^{HL}} = \pi(HL)\left(1-\gamma(HL)\right)\left(\theta_1^H v'\left(g_{1N}^{HL}\right) - c'\left(g_{1N}^{HL}\right)\right) \overset{!}{=} 0 \qquad (10)$$

$$\frac{\partial EU}{\partial g_{2N}^{HL}} = \pi(HL)\left(1-\gamma(HL)\right)\left(\theta_2^L v'\left(g_{2N}^{HL}\right) - c'\left(g_{2N}^{HL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1N}^{HH}} = \pi(HH)\left(1-\gamma(HH)\right)\left(\theta_1^H v'\left(g_{1N}^{HH}\right) - c'\left(g_{1N}^{HH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2N}^{HH}} = \pi(HH)\left(1-\gamma(HH)\right)\left(\theta_2^H v'\left(g_{2N}^{HH}\right) - c'\left(g_{2N}^{HH}\right)\right) \overset{!}{=} 0$$

If the government were to perform an audit, it would have to solve the following conditions:

(11)

$$\frac{\partial EU}{\partial g_{1A}^{LL}} = \pi(LL)\gamma(LL)\left(\theta_1^L v'\left(g_{1A}^{LL}\right) - c'\left(g_{1A}^{LL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2A}^{LL}} = \pi(LL)\gamma(LL)\left(\theta_2^L v'\left(g_{2A}^{LL}\right) - c'\left(g_{2A}^{LL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1A}^{LH}} = \pi(LH)\gamma(LH)\left(\theta_1^L v'\left(g_{1A}^{LH}\right) - c'\left(g_{1A}^{LH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2A}^{LH}} = \pi(LH)\gamma(LH)\left(\theta_2^H v'\left(g_{2A}^{LH}\right) - c'\left(g_{2A}^{LH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1A}^{HL}} = \pi(HL)\gamma(HL)\left(\theta_1^H v'\left(g_{1A}^{HL}\right) - c'\left(g_{1A}^{HL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2A}^{HL}} = \pi(HL)\gamma(LH)\left(\theta_2^L v'\left(g_{2A}^{HL}\right) - c'\left(g_{2A}^{HL}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{1A}^{HH}} = \pi(HH)\gamma(HH)\left(\theta_1^H v'\left(g_{1A}^{HH}\right) - c'\left(g_{1A}^{HH}\right)\right) \overset{!}{=} 0$$

$$\frac{\partial EU}{\partial g_{2A}^{HH}} = \pi(HH)\gamma(HH)\left(\theta_2^H v'\left(g_{2A}^{HH}\right) - c'\left(g_{2A}^{HH}\right)\right) \overset{!}{=} 0$$

The solutions to these 8 equations obviously hold if the traditional first-best amounts of the public goods are provided, i.e. each level of public good is set to solve $\theta_i^\alpha v'\left(g_{iN}^\alpha\right) - c'\left(g_{iN}^\alpha\right) = 0$, $i = 1,2$, $\alpha \in \{LL, LH, HL, HH\}$ in states of the world where no audit takes place. Analogously, $\theta_i^\alpha v'\left(g_{iA}^\alpha\right) - c'\left(g_{iA}^\alpha\right) = 0$, $i = 1,2$, $\alpha \in \{LL, LH, HL, HH\}$ is set when an audit has taken place..

The optimality conditions with respect to the audit probabilities are

$$\frac{\partial EU}{\partial \gamma(LL)} = h(LL) = \pi(LL)\begin{pmatrix} \left\{Y + \theta_1^L v\left(g_{1A}^{LL}\right) + \theta_2^L v\left(g_{2A}^{LL}\right) - c\left(g_{1A}^{LL}\right) - c\left(g_{2A}^{LL}\right) - q\right\} \\ -\left\{Y + \theta_1^L v\left(g_{1N}^{LL}\right) + \theta_2^L v\left(g_{2N}^{LL}\right) - c\left(g_{1N}^{LL}\right) - c\left(g_{2N}^{LL}\right)\right\} \end{pmatrix}$$

where $h(LL)$ is used as a shortcut to denote this coefficient, because the complementary slackness conditions from the Kuhn-Tucker problem read either $\gamma(LL) > 0$ implying $h(LL) = 0$ or $\gamma(LL) = 0$ and $h(LL) \neq 0$. The coefficients for the other audit probabilities are similar:

$$\frac{\partial EU}{\partial \gamma(LH)} = h(LH) = \pi(LH)\begin{pmatrix} \left\{Y + \theta_1^L v\left(g_{1A}^{LH}\right) + \theta_2^H v\left(g_{2A}^{LH}\right) - c\left(g_{1A}^{LH}\right) - c\left(g_{2A}^{LH}\right) - q\right\} \\ -\left\{Y + \theta_1^L v\left(g_{1N}^{LH}\right) + \theta_2^H v\left(g_{2N}^{LH}\right) - c\left(g_{1N}^{LH}\right) - c\left(g_{2N}^{LH}\right)\right\} \end{pmatrix}$$

$$\frac{\partial EU}{\partial \gamma(HL)} = h(HL) = \pi(HL)\begin{pmatrix} \left\{Y + \theta_1^H v\left(g_{1A}^{HL}\right) + \theta_2^L v\left(g_{2A}^{HL}\right) - c\left(g_{1A}^{HL}\right) - c\left(g_{2A}^{HL}\right) - q\right\} \\ -\left\{Y + \theta_1^H v\left(g_{1N}^{HL}\right) + \theta_2^L v\left(g_{2N}^{HL}\right) - c\left(g_{1N}^{HL}\right) - c\left(g_{2N}^{HL}\right)\right\} \end{pmatrix}$$

$$\frac{\partial EU}{\partial \gamma(HH)} = h(HH) = \pi(HH)\begin{pmatrix} \left\{Y + \theta_1^H v\left(g_{1A}^{HH}\right) + \theta_2^H v\left(g_{2A}^{HH}\right) - c\left(g_{1A}^{HH}\right) - c\left(g_{2A}^{HH}\right) - q\right\} \\ -\left\{Y + \theta_1^H v\left(g_{1N}^{HH}\right) + \theta_2^H v\left(g_{2N}^{HH}\right) - c\left(g_{1N}^{HH}\right) - c\left(g_{2N}^{HH}\right)\right\} \end{pmatrix}$$

Now equations (10) and (11) imply that no matter whether an audit has taken place or not, the first best optimal amounts of the public goods will be chosen in all states of the world. The Samuelson-condition of the present model just states that the marginal benefit from each type of public goods should be equalized with its marginal production cost.[12]

[12] See e.g. Sinn (1997) for a contribution which analyses the consequences of varying marginal costs in the supply of public goods.

If this fact is used in the set of coefficients $\{h(LL), h(LH), h(HL), h(HH)\}$, it is easily seen that all of these coefficients are negative. Hence the complementary slackness conditions imply that the set of audit probabilities must be set to zero: $\{\gamma(LL), \gamma(LH), \gamma(HL), \gamma(HH)\} = \{0,0,0,0\}$.

We summarize the result in Proposition 1:

Proposition 1

If there is no asymmetric information between the agency and the government,

- no audits will performed.
- the optimal supply of public goods according to the Samuelson-conditions will be supplied in every state of the world.

The logic for this result is obvious. Given that an audit does not provide additional information about the amounts of public goods to be provided, but results in costs for the government, it is never optimal to perform one in this situation.

The result provides, however, a stepping stone for the situation with asymmetric information. It could be expected that there exists a state of the world, e.g. HH, in which the information that can be gained via an audit is so important for the government, that it will conduct an audit in that state irrespective of the report of the agent.

This expectation does not bear out. Under asymmetric information, it is never optimal for the government to always audit the agency:

Proposition 2: If $q > 0$ then $\gamma(\alpha) < 1, \quad \forall \alpha \in \{LL, LH, HL, HH\}$

Proof:

Suppose there exists a solution in which the message that the state of the world is $\alpha = HH$ leads to the fact that the agency is always being audited, $\gamma(HH) = 1$. Let a new solution (γ', g') have the property that in all other states of the world $s \neq (HH)$, the audit probabilities and the allocated budgets remain the same as in the original solution,

$\gamma'(s) = \gamma(s), g'^{s}_{ij} = g^{s}_{ij}, i = 1,2, j = N, A, s \neq (HH)$. Only the message "$HH$" results in an audit with a different probability than in the old solution. In the new solution the audit is performed only with the reduced probability $1-\varepsilon$, ε sufficiently small but strictly positive.. The allocated budgets and hence the size of the public facilities remains the same: $g'^{HH}_{ij} = g^{HH}_{ij}, i = 1,2, j = N, A$. The new solution obeys all incentive compatibility constraints between the other states of the world differing from HH, because nothing was changed with respect to those. For state HH, we have to look at the third parts of (6)-(8): In the old solution these where strictly non- binding, because with $\gamma(HH) = 1$, the expected utility for the agency is be strictly positive, if it tells the truth. Under the new solution the utility from truth-telling must cover the now positive utility from a possible successful misrepresentation, given by

$$\varepsilon\left(b(L)g_{1N}^{HH}+b(L)g_{2N}^{HH}\right)$$

if type LL is lying and similarly for types LH and HL. If $\varepsilon > 0$ is sufficiently small, all three incentive compatibility constraints will not be violated. On the other hand, reducing the probability of an audit of the message "HH" from unity to $1-\varepsilon$ reduces the expected cost of the mechanism by

$$\pi(HH)\varepsilon q > 0,$$

generating a welfare improvement without any cost. The reasoning can be replicated for any state of the world. Hence it is never optimal to always audit.[13]

The intuition for this result is that it is never optimal to always audit a specific message of the agency is that a stochastic audit with a probability less than one exhibits the same incentive effects as a certain audit, but at a lesser cost to the government and hence to the representative consumer in terms of taxes which have to be paid to finance the costs of the audit.

If informational asymmetry is present, the first order conditions of the problem of the government for the optimal supply of the local public goods when it does not conduct an audit are

For g_{1N}^{LL}:

$$\begin{aligned}&\pi(LL)(1-\gamma(LL))\left(\theta_1^{LL}v'\left(g_{1N}^{LL}\right)-c'\left(g_{1N}^{LL}\right)\right)\\&+\mu_{LL,LH}\left((1-\gamma(LL))b(L)\right)+\mu_{LL,HL}\left((1-\gamma(LL))b(L)\right)+\mu_{LL,HH}\left((1-\gamma(LL))b(L)\right)\\&-\mu_{LH,LL}\left((1-\gamma(LL))b(L)\right)-\mu_{HL,LL}\left((1-\gamma(LL))b(H)\right)-\mu_{HH,LL}\left((1-\gamma(LL))b(H)\right)=0\end{aligned} \tag{12}$$

For g_{2N}^{LL}

$$\begin{aligned}&\pi(LL)(1-\gamma(LL))\left(\theta_2^{LL}v'\left(g_{2N}^{LL}\right)-c'\left(g_{2N}^{LL}\right)\right)\\&+\mu_{LL,LH}\left((1-\gamma(LL))b(L)\right)+\mu_{LL,HL}\left((1-\gamma(LL))b(L)\right)+\mu_{LL,HH}\left((1-\gamma(LL))b(L)\right)\\&-\mu_{LH,LL}\left((1-\gamma(LL))b(H)\right)-\mu_{HL,LL}\left((1-\gamma(LL))b(L)\right)-\mu_{HH,LL}\left((1-\gamma(LL))b(H)\right)=0\end{aligned} \tag{13}$$

For g_{1N}^{LH}

[13] Cf. Harris/Raviv (1998).

$$\pi(LH)(1-\gamma(LH))\left(\theta_1^{LH}v'\left(g_{1N}^{LH}\right)-c'\left(g_{1N}^{LH}\right)\right)$$
$$+\mu_{LH,LL}\left((1-\gamma(LH))b(L)\right)+\mu_{LH,HL}\left((1-\gamma(LH))b(L)\right)+\mu_{LH,HH}\left((1-\gamma(LH))b(L)\right)$$
$$-\mu_{LL,LH}\left((1-\gamma(LH))b(L)\right)-\mu_{HL,LH}\left((1-\gamma(LH))b(H)\right)-\mu_{HH,LH}\left((1-\gamma(LH))b(H)\right)=0$$

(14)

For g_{2N}^{LH}

$$\pi(LH)(1-\gamma(LH))\left(\theta_2^{LH}v'\left(g_{2N}^{LH}\right)-c'\left(g_{2N}^{LH}\right)\right)$$
$$+\mu_{LH,LL}\left((1-\gamma(LH))b(H)\right)+\mu_{LH,HL}\left((1-\gamma(LH))b(H)\right)+\mu_{LH,HH}\left((1-\gamma(LH))b(H)\right)$$
$$-\mu_{LL,LH}\left((1-\gamma(LH))b(L)\right)-\mu_{HL,LH}\left((1-\gamma(LH))b(L)\right)-\mu_{HH,LH}\left((1-\gamma(LH))b(H)\right)=0$$

(15)

For g_{1N}^{HL}

$$\pi(HL)(1-\gamma(HL))\left(\theta_1^{HL}v'\left(g_{1N}^{HL}\right)-c'\left(g_{1N}^{HL}\right)\right)$$
$$+\mu_{HL,LL}\left((1-\gamma(HL))b(H)\right)+\mu_{HL,LH}\left((1-\gamma(HL))b(H)\right)+\mu_{HL,HH}\left((1-\gamma(HL))b(H)\right)$$
$$-\mu_{LL,HL}\left((1-\gamma(HL))b(L)\right)-\mu_{LH,HL}\left((1-\gamma(HL))b(L)\right)-\mu_{HH,HL}\left((1-\gamma(HL))b(H)\right)=0$$

(16)

For g_{2N}^{HL}

$$\pi(HL)(1-\gamma(HL))\left(\theta_2^{HL}v'\left(g_{2N}^{HL}\right)-c'\left(g_{2N}^{HL}\right)\right)$$
$$+\mu_{HL,LL}\left((1-\gamma(HL))b(L)\right)+\mu_{HL,LH}\left((1-\gamma(HL))b(L)\right)+\mu_{HL,HH}\left((1-\gamma(HL))b(L)\right)$$
$$-\mu_{LL,HL}\left((1-\gamma(HL))b(L)\right)-\mu_{LH,HL}\left((1-\gamma(HL))b(H)\right)-\mu_{HH,HL}\left((1-\gamma(HL))b(H)\right)=0$$

(17)

For g_{1N}^{HH}

$$\pi(HH)(1-\gamma(HH))\left(\theta_1^{HH}v'\left(g_{1N}^{HH}\right)-c'\left(g_{1N}^{HH}\right)\right)$$
$$+\mu_{HH,LL}\left((1-\gamma(HH))b(H)\right)+\mu_{HH,LH}\left((1-\gamma(HH))b(H)\right)+\mu_{HH,HL}\left((1-\gamma(HH))b(H)\right)$$
$$-\mu_{LL,HH}\left((1-\gamma(HH))b(L)\right)-\mu_{LH,HH}\left((1-\gamma(HH))b(L)\right)-\mu_{HL,HH}\left((1-\gamma(HH))b(H)\right)=0$$

(18)

For g_{2N}^{HH}

$$\pi(HH)(1-\gamma(HH))\left(\theta_2^{HH}v'\left(g_{2N}^{HH}\right)-c'\left(g_{2N}^{HH}\right)\right)$$
$$+\mu_{HH,LL}\left((1-\gamma(HH))b(H)\right)+\mu_{HH,LH}\left((1-\gamma(HH))b(H)\right)+\mu_{HH,HL}\left((1-\gamma(HH))b(H)\right)$$
$$-\mu_{LL,HH}\left((1-\gamma(HH))b(L)\right)-\mu_{LH,HH}\left((1-\gamma(HH))b(H)\right)-\mu_{HL,HH}\left((1-\gamma(HH))b(L)\right)=0$$

(19)

The first order conditions for the optimal levels of the public goods when the government has audited the agency are given by

For g_{1A}^{LL}

$$\pi(LL)\gamma(LL)\left(\theta_1^{LL}v'\left(g_{1A}^{LL}\right)-c'\left(g_{1A}^{LL}\right)\right)$$
$$+\mu_{LL,LH}\gamma(LL)b(L)+\mu_{LL,HL}\gamma(LL)b(L)+\mu_{LL,HH}\gamma(LL)b(L)=0 \quad (20)$$

For g_{2A}^{LL}

$$\pi(LL)\gamma(LL)\left(\theta_2^{LL}v'\left(g_{2A}^{LL}\right)-c'\left(g_{2A}^{LL}\right)\right)$$
$$+\mu_{LL,LH}\gamma(LL)b(L)+\mu_{LL,HL}\gamma(LL)b(L)+\mu_{LL,HH}\gamma(LL)b(L)=0 \quad (21)$$

For g_{1A}^{LH}

$$\pi(LH)\gamma(LH)\left(\theta_1^{LH}v'\left(g_{1A}^{LH}\right)-c'\left(g_{1A}^{LH}\right)\right)$$
$$+\mu_{LH,LL}\gamma(LH)b(L)+\mu_{LH,HL}\gamma(LH)b(L)+\mu_{LH,HH}\gamma(LH)b(L)=0 \quad (22)$$

For g_{2A}^{LH}

$$\pi(LH)\gamma(LH)\left(\theta_2^{LH}v'\left(g_{2A}^{LH}\right)-c'\left(g_{2A}^{LH}\right)\right)$$
$$+\mu_{LH,LL}\gamma(LH)b(H)+\mu_{LH,HL}\gamma(LH)b(H)+\mu_{LH,HH}\gamma(LH)b(H)=0 \quad (23)$$

For g_{1A}^{HL}

$$\pi(HL)\gamma(HL)\left(\theta_1^{HL}v'\left(g_{1A}^{HL}\right)-c'\left(g_{1A}^{HL}\right)\right)$$
$$+\mu_{HL,LL}\gamma(HL)b(H)+\mu_{HL,LH}\gamma(HL)b(H)+\mu_{HL,HH}\gamma(HL)b(H)=0 \quad (24)$$

For g_{2A}^{HL}

$$\pi(HL)\gamma(HL)\left(\theta_2^{HL}v'\left(g_{2A}^{HL}\right)-c'\left(g_{2A}^{HL}\right)\right)$$
$$+\mu_{HL,LL}\gamma(HL)b(L)+\mu_{HL,LH}\gamma(HL)b(L)+\mu_{HL,HH}\gamma(HL)b(L)=0 \quad (25)$$

For g_{1A}^{HH}

$$\pi(HH)\gamma(HH)\left(\theta_1^{HH}v'\left(g_{1A}^{HH}\right)-c'\left(g_{1A}^{HH}\right)\right)$$
$$+\mu_{HH,LL}\gamma(HH)b(H)+\mu_{HH,LH}\gamma(HH)b(H)+\mu_{HH,HL}\gamma(HH)b(H)=0 \tag{26}$$

For g_{2A}^{HH}

$$\pi(HH)\gamma(HH)\left(\theta_2^{HH}v'\left(g_{2A}^{HH}\right)-c'\left(g_{2A}^{HH}\right)\right)$$
$$+\mu_{HH,LL}\gamma(HH)b(H)+\mu_{HH,LH}\gamma(HH)b(H)+\mu_{HH,HL}\gamma(HH)b(H)=0 \tag{27}$$

If we factor out the terms containing audit probabilities and add and subtract the terms with Lagrangian multipliers in equations (12)-(19) to move them to the respective right hand sides of the equations and then add the resulting expressions we get

$$\begin{aligned}&\pi(LL)\left(\theta_{1N}^{LL}v'\left(g_{1N}^{LL}\right)-c'\left(g_{1N}^{LL}\right)+\theta_{2N}^{LL}v'\left(g_{2N}^{LL}\right)-c'\left(g_{2N}^{LL}\right)\right)\\&+\pi(LH)\left(\theta_{1N}^{LH}v'\left(g_{1N}^{LH}\right)-c'\left(g_{1N}^{LH}\right)+\theta_{2N}^{LH}v'\left(g_{2N}^{LH}\right)-c'\left(g_{2N}^{LH}\right)\right)\\&+\pi(HL)\left(\theta_{1N}^{HL}v'\left(g_{1N}^{HL}\right)-c'\left(g_{1N}^{HL}\right)+\theta_{2N}^{HL}v'\left(g_{2N}^{HL}\right)-c'\left(g_{2N}^{HL}\right)\right)\\&+\pi(HH)\left(\theta_{1N}^{HH}v'\left(g_{1N}^{HH}\right)-c'\left(g_{1N}^{HH}\right)+\theta_{2N}^{HH}v'\left(g_{2N}^{HH}\right)-c'\left(g_{2N}^{HH}\right)\right)=0\end{aligned} \tag{28}$$

because all terms containing Lagrangian multipliers cancel out in the summation.

This equation has to hold for any solution of the problem of the government. It incorporates all first order conditions for the different amounts of public goods into one. Because of the assumptions about the functional forms of $v(\cdot)$ and $c(\cdot)$ it is clear that the left-hand side of this equation is monotone decreasing in all public good levels $g_{ij}^{\alpha}, i=1,2, j=N,A,\alpha\in\{LL,LH,HL,HH\}$.

To determine the optimal audit probabilities, one again has to differentiate the Lagrangian with respect to the audit probabilities and gets the following coefficients $h(\alpha)$ for probability $\gamma(\alpha)$

For $\gamma(LL)$

$$\begin{aligned}h(LL)=\pi(LL)&\begin{pmatrix}-q\\+\theta_1^{LL}v\left(g_{1A}^{LL}\right)+\theta_2^{LL}v\left(g_{2A}^{LL}\right)-c\left(g_{1A}^{LL}\right)-c\left(g_{2A}^{LL}\right)\\-\left(\theta_1^{LL}v\left(g_{1N}^{LL}\right)+\theta_2^{LL}v\left(g_{2N}^{LL}\right)-c\left(g_{1N}^{LL}\right)-c\left(g_{2N}^{LL}\right)\right)\end{pmatrix}\\&+\mu_{LL,LH}\left(-\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right)\right)\\&+\mu_{LL,HL}\left(-\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right)\right)\\&+\mu_{LL,HH}\left(-\left(b(L)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)+\left(b(L)g_{1A}^{LL}+b(L)g_{2A}^{LL}\right)\right)\\&+\mu_{LH,LL}\left(\left(b(L)g_{1N}^{LL}+b(H)g_{2N}^{LL}\right)\right)\\&+\mu_{HL,LL}\left(\left(b(H)g_{1N}^{LL}+b(L)g_{2N}^{LL}\right)\right)\\&+\mu_{HH,LL}\left(\left(b(H)g_{1N}^{LL}+b(H)g_{2N}^{LL}\right)\right)\end{aligned} \tag{29}$$

For $\gamma(LH)$

$$h(LH)=\pi(LH)\begin{pmatrix}-q\\ +\theta_1^{LH}v\left(g_{1A}^{LH}\right)+\theta_2^{LH}v\left(g_{2A}^{LH}\right)-c\left(g_{1A}^{LH}\right)-c\left(g_{2A}^{LH}\right)\\ -\left(\theta_1^{LH}v\left(g_{1N}^{LH}\right)+\theta_2^{LH}v\left(g_{2N}^{LH}\right)-c\left(g_{1N}^{LH}\right)-c\left(g_{2N}^{LH}\right)\right)\end{pmatrix}$$
$$+\mu_{LH,LL}\left(-\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\right)$$
$$+\mu_{LH,HL}\left(-\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\right)$$
$$+\mu_{LH,HH}\left(-\left(b(L)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)+\left(b(L)g_{1A}^{LH}+b(H)g_{2A}^{LH}\right)\right) \quad (30)$$
$$+\mu_{LL,LH}\left(\left(b(L)g_{1N}^{LH}+b(L)g_{2N}^{LH}\right)\right)$$
$$+\mu_{HL,LH}\left(\left(b(H)g_{1N}^{LH}+b(L)g_{2N}^{LH}\right)\right)$$
$$+\mu_{HH,LH}\left(\left(b(H)g_{1N}^{LH}+b(H)g_{2N}^{LH}\right)\right)$$

For $\gamma(HL)$

$$h(HL)=\pi(HL)\begin{pmatrix}-q\\ +\theta_1^{HL}v\left(g_{1A}^{HL}\right)+\theta_2^{HL}v\left(g_{2A}^{HL}\right)-c\left(g_{1A}^{HL}\right)-c\left(g_{2A}^{HL}\right)\\ -\left(\theta_1^{HL}v\left(g_{1N}^{HL}\right)+\theta_2^{HL}v\left(g_{2N}^{HL}\right)-c\left(g_{1N}^{HL}\right)-c\left(g_{2N}^{HL}\right)\right)\end{pmatrix}$$
$$+\mu_{HL,LL}\left(-\left(b(L)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)+\left(b(L)g_{1A}^{HL}+b(H)g_{2A}^{HL}\right)\right)$$
$$+\mu_{HL,LH}\left(-\left(b(L)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)+\left(b(L)g_{1A}^{HL}+b(H)g_{2A}^{HL}\right)\right)$$
$$+\mu_{HL,HH}\left(-\left(b(L)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)+\left(b(L)g_{1A}^{HL}+b(H)g_{2A}^{HL}\right)\right) \quad (31)$$
$$+\mu_{LL,HL}\left(\left(b(L)g_{1N}^{HL}+b(L)g_{2N}^{HL}\right)\right)$$
$$+\mu_{LH,HL}\left(\left(b(L)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)\right)$$
$$+\mu_{HH,HL}\left(\left(b(H)g_{1N}^{HL}+b(H)g_{2N}^{HL}\right)\right)$$

For $\gamma(HH)$

$$h(HH)=\pi(HH)\begin{pmatrix}-q\\ +\theta_1^{HH}v\left(g_{1A}^{HH}\right)+\theta_2^{HH}v\left(g_{2A}^{HH}\right)-c\left(g_{1A}^{HH}\right)-c\left(g_{2A}^{HH}\right)\\ -\left(\theta_1^{HH}v\left(g_{1N}^{HH}\right)+\theta_2^{HH}v\left(g_{2N}^{HH}\right)-c\left(g_{1N}^{HH}\right)-c\left(g_{2N}^{HH}\right)\right)\end{pmatrix}$$
$$+\mu_{HH,LL}\left(-\left(b(L)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\left(b(L)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\right)$$
$$+\mu_{HH,LH}\left(-\left(b(L)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\left(b(L)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\right)$$
$$+\mu_{HH,HL}\left(-\left(b(L)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)+\left(b(L)g_{1A}^{HH}+b(H)g_{2A}^{HH}\right)\right) \qquad (32)$$
$$+\mu_{LL,HH}\left(\left(b(L)g_{1N}^{HH}+b(L)g_{2N}^{HH}\right)\right)$$
$$+\mu_{LH,HH}\left(\left(b(L)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)\right)$$
$$+\mu_{HL,HH}\left(\left(b(H)g_{1N}^{HH}+b(H)g_{2N}^{HH}\right)\right)$$

It was already demonstrated that the optimal auditing probability will be less than unity in all states of the world, i.e. for all types of agency preferences. The Kuhn-Tucker complementary slackness conditions again state that if $\gamma(\alpha)=0$, $h(\alpha)>0$ and if $\gamma(\alpha)>0$, $h(\alpha)=0$ must hold. In equations (29)-(32) one can substitute for the terms containing Lagrangian multipliers from equations (12)-(27). E.g., from (12), one can substitute in (29)

$$-\mu_{LL,LH}b(L)-\mu_{LL,HL}b(L)-\mu_{LL,HH}b(L)$$
$$+\mu_{LH,LL}b(L)+\mu_{HL,LL}b(H)+\mu_{HH,LL}b(H)=\pi(LL)\left(\theta_1^{LL}v'\left(g_{1N}^{LL}\right)-c'\left(g_{1N}^{LL}\right)\right)$$

and similarly from (13), (20) and (21) for the terms relating to $g_{2N}^{LL}, g_{1A}^{LL}, g_{2A}^{LL}$. Dividing by $\pi(LL)$ and rearranging terms, one gets

$$\frac{h(LL)}{\pi(LL)}=-q+\theta_1^{LL}v\left(g_{1A}^{LL}\right)-c\left(g_{1A}^{LL}\right)-g_{1A}^{LL}\left(\theta_1^{LL}v'\left(g_{1A}^{LL}\right)-c'\left(g_{1A}^{LL}\right)\right)$$
$$+\theta_2^{LL}v\left(g_{2A}^{LL}\right)-c\left(g_{2A}^{LL}\right)-g_{2A}^{LL}\left(\theta_2^{LL}v'\left(g_{2A}^{LL}\right)-c'\left(g_{2A}^{LL}\right)\right) \qquad (33)$$
$$-\begin{pmatrix}\theta_1^{LL}v\left(g_{1N}^{LL}\right)-c\left(g_{1N}^{LL}\right)-g_{1N}^{LL}\left(\theta_1^{LL}v'\left(g_{1N}^{LL}\right)-c'\left(g_{1N}^{LL}\right)\right)\\ +\theta_2^{LL}v\left(g_{2N}^{LL}\right)-c\left(g_{2N}^{LL}\right)-g_{2N}^{LL}\left(\theta_2^{LL}v'\left(g_{2N}^{LL}\right)-c'\left(g_{2N}^{LL}\right)\right)\end{pmatrix}$$

Working along the same lines for the other equations results in

$$\frac{h(LH)}{\pi(LH)} = -q + \theta_1^{LH} v\left(g_{1A}^{LH}\right) - c\left(g_{1A}^{LH}\right) - g_{1A}^{LH}\left(\theta_1^{LH} v'\left(g_{1A}^{LH}\right) - c'\left(g_{1A}^{LH}\right)\right)$$
$$+ \theta_2^{LH} v\left(g_{2A}^{LH}\right) - c\left(g_{2A}^{LH}\right) - g_{2A}^{LH}\left(\theta_2^{LH} v'\left(g_{2A}^{LH}\right) - c'\left(g_{2A}^{LH}\right)\right) \tag{34}$$
$$- \begin{pmatrix} \theta_1^{LH} v\left(g_{1N}^{LH}\right) - c\left(g_{1N}^{LH}\right) - g_{1N}^{LH}\left(\theta_1^{LH} v'\left(g_{1N}^{LH}\right) - c'\left(g_{1N}^{LH}\right)\right) \\ +\theta_2^{LH} v\left(g_{2N}^{LH}\right) - c\left(g_{2N}^{LH}\right) - g_{2N}^{LH}\left(\theta_2^{LH} v'\left(g_{2N}^{LH}\right) - c'\left(g_{2N}^{LH}\right)\right) \end{pmatrix}$$

$$\frac{h(HL)}{\pi(HL)} = -q + \theta_1^{HL} v\left(g_{1A}^{HL}\right) - c\left(g_{1A}^{HL}\right) - g_{1A}^{HL}\left(\theta_1^{HL} v'\left(g_{1A}^{HL}\right) - c'\left(g_{1A}^{HL}\right)\right)$$
$$+ \theta_2^{HL} v\left(g_{2A}^{HL}\right) - c\left(g_{2A}^{HL}\right) - g_{2A}^{HL}\left(\theta_2^{HL} v'\left(g_{2A}^{HL}\right) - c'\left(g_{2A}^{HL}\right)\right) \tag{35}$$
$$- \begin{pmatrix} \theta_1^{HL} v\left(g_{1N}^{HL}\right) - c\left(g_{1N}^{HL}\right) - g_{1N}^{HL}\left(\theta_1^{HL} v'\left(g_{1N}^{HL}\right) - c'\left(g_{1N}^{HL}\right)\right) \\ +\theta_2^{HL} v\left(g_{2N}^{HL}\right) - c\left(g_{2N}^{HL}\right) - g_{2N}^{HL}\left(\theta_2^{HL} v'\left(g_{2N}^{HL}\right) - c'\left(g_{2N}^{HL}\right)\right) \end{pmatrix}$$

and

$$\frac{h(HH)}{\pi(HH)} = -q + \theta_1^{HH} v\left(g_{1A}^{HH}\right) - c\left(g_{1A}^{HH}\right) - g_{1A}^{HH}\left(\theta_1^{HH} v'\left(g_{1A}^{HH}\right) - c'\left(g_{1A}^{HH}\right)\right)$$
$$+ \theta_2^{HH} v\left(g_{2A}^{HH}\right) - c\left(g_{2A}^{HH}\right) - g_{2A}^{HH}\left(\theta_2^{HH} v'\left(g_{2A}^{HH}\right) - c'\left(g_{2A}^{HH}\right)\right) \tag{36}$$
$$- \begin{pmatrix} \theta_1^{HH} v\left(g_{1N}^{HH}\right) - c\left(g_{1N}^{HH}\right) - g_{1N}^{HH}\left(\theta_1^{HH} v'\left(g_{1N}^{HH}\right) - c'\left(g_{1N}^{HH}\right)\right) \\ +\theta_2^{HH} v\left(g_{2N}^{HH}\right) - c\left(g_{2N}^{HH}\right) - g_{2N}^{HH}\left(\theta_2^{HH} v'\left(g_{2N}^{HH}\right) - c'\left(g_{2N}^{HH}\right)\right) \end{pmatrix}$$

As long as there is an audit with positive probability in any given state of the world, expressions (33)-(36) must be equal to zero. They then yield a relationship between the size of the auditing costs and the levels of the public goods that are to be provided, both in circumstances where no audit takes place and when an audit has been performed. Furthermore, how the public goods levels evolve is governed by the functional relationship between the net benefit derived from each public good in each circumstance, e.g. $\theta_1^{HH} v\left(g_{1A}^{HH}\right) - c\left(g_{1A}^{HH}\right)$ from (36) when HH has been realized and an audit has been performed, and the respective net marginal benefit multiplied by the amount of the public good, $g_{1A}^{HH}\left(\theta_1^{HH} v'\left(g_{1A}^{HH}\right) - c'\left(g_{1A}^{HH}\right)\right)$.

Because of symmetry of the model the solution to the problem of the government will exhibit the following properties:

$$g_{1A}^{LL} = g_{2A}^{LL}, \quad g_{1N}^{LL} = g_{2N}^{LL}, \quad g_{1A}^{HH} = g_{2A}^{HH}, \quad g_{1N}^{HH} = g_{2N}^{HH},$$
$$g_{1A}^{LH} = g_{2A}^{HL}, \quad g_{1A}^{HL} = g_{2A}^{LH}, \quad g_{1N}^{LH} = g_{2N}^{HL}, \quad g_{1N}^{HL} = g_{2N}^{LH}$$
$$\gamma(LH) = \gamma(HL) \tag{37}$$

Let the solution to the problem of the government be denoted by[14]

$$g_{1A}^{LL}=g_{2A}^{LL}=g_{A*}^{LL}(q),\quad g_{1N}^{LL}=g_{2N}^{LL}=g_{N*}^{LL}(q),$$
$$g_{1A}^{HH}=g_{2A}^{HH}=g_{A*}^{HH}(q),\quad g_{1N}^{HH}=g_{2N}^{HH}=g_{N*}^{HH}(q),$$

for the "pure" states of the world and

$$g_{1A}^{LH}=g_{2A}^{HL}=g_{A}^{L*}(q),\quad g_{1A}^{HL}=g_{2A}^{LH}=g_{A}^{H*}(q),$$
$$g_{1N}^{LH}=g_{2N}^{HL}=g_{N}^{L*}(q),\quad g_{1N}^{HL}=g_{2N}^{LH}=g_{N}^{H*}(q)$$

for the "mixed" states of the world. Furthermore,

$$\gamma*(LL,q)=\gamma(LL,q),\gamma*(LH,q)=\gamma(LH,q)=\gamma(HL,q),\gamma*(HH,q)=\gamma(HH,q).$$

The strongest incentive to misrepresent the available information has an agency decision maker with information (LL) because he will get the smallest size of the public facilities possible if he sends this information truthfully to the government. As this will also lead to a low utility for the decision maker, he has the biggest incentive to misrepresent to the government in order to get bigger facilities. It will be shown that only the incentive compatibility constraints of this type of decision maker bind at the optimum. Starting with the conjecture that this is the case, only $\mu_{LL,LH},\mu_{LL,HL},\mu_{LL,HH}$ will be positive and all other Lagrangian multipliers must be equal to zero because of the Kuhn-Tucker conditions. This implies that in (12)-(27) all Lagrangian terms not containing those three multipliers vanish. These equations then imply for circumstances without an audit,

$$\mu_{LL,LH}\big(b(L)\big)=\pi(LH)\Big(\theta_1^{LH}v'\big(g_{L*}^{LH}\big)-c'\big(g_{L*}^{LH}\big)\Big)=\pi(LH)\Big(\theta_2^{LH}v'\big(g_{H*}^{LH}\big)-c'\big(g_{H*}^{LH}\big)\Big) \quad (38)$$

from (14) and (15),

$$\mu_{LL,HL}\big(b(L)\big)=\pi(HL)\Big(\theta_1^{HL}v'\big(g_{H*}^{HL}\big)-c'\big(g_{H*}^{HL}\big)\Big)=\pi(HL)\Big(\theta_2^{HL}v'\big(g_{L*}^{HL}\big)-c'\big(g_{L*}^{HL}\big)\Big) \quad (39)$$

from (16) and (17)

and finally

$$\mu_{LL,HH}\big(b(L)\big)=\pi(HH)\Big(\theta_1^{HH}v'\big(g_{*}^{HH}\big)-c'\big(g_{*}^{HH}\big)\Big)=\pi(HH)\Big(\theta_2^{HH}v'\big(g_{*}^{HH}\big)-c'\big(g_{*}^{HH}\big)\Big) \quad (40)$$

from (18) and (19). Thus, in circumstances without an audit the solution of the problem of the government will exhibit the intuitively plausible property that net marginal benefits from the different types of public goods will be equalized within each realized state of the world.

[14] To simplify the exposition the dependency of the optimal solutions on the given level of q will be suppressed whenever this does not cause confusion.

In other words, these three conditions imply that at the optimal solution the available funds will be used by the agency in such a way that the net marginal benefits from supplying additional units of the two public goods by spending another tax dollar will be equalized in all states of the world. The agency will thus use the funds made available to it in a welfare maximizing way. The reason for this is that by assumption the interests of the decision maker of the agency and the government (and thus the representative household) are aligned in the sense that both give the same relative importance to the two types of public goods and there is therefore no inefficiency in the mix of public goods chosen by the agency. This contrasts with the approach taken by Gordon/Wilson (1999) where the decisive public official prefers a different bundle of public goods than the representative household. The household must then use the tax system (via the elected government which determines the tax system whereas the official determines the expenditure mix of public goods) to influence the expenditure decisions of the public official in such a way that the resulting deviations from the preferences of the household are reduced/minimized.

Equations (22)-(27) imply that post audit (implying a strictly positive probability of conducting an audit) the government, after getting to know the true state of the world will again use this information to provide the first-best amounts of the public goods. This implies that net marginal benefits from the public goods will be equalized not only within but also between states of the world whenever an audit has taken place.

Equations (20) and (21) on the other hand can hold only if the government were to provide a greater than first-best optimal supply of the public goods post audit in state LL. It is less costly in terms of its objective to never conduct an audit in state LL, and with $\gamma^*(LL)=0$, equations (20) and (21) will hold identically.

Using the notation for the solution of the government and the symmetry of the problem with respect to states LH and HL, the following five equations determine how the solution of the problem evolves depending on the level of the audit costs q:

$$\begin{aligned}&\pi(LL)2\left(\theta^L v'\left(g_*^{LL}\right)-c'\left(g_*^{LL}\right)\right)\\&+\left(\pi(LH)+\pi(HL)\right)\left(\theta^L v'\left(g_N^{L*}\right)-c'\left(g_N^{L*}\right)+\theta^H v'\left(g_N^{H*}\right)-c'\left(g_N^{H*}\right)\right)\\&+\pi(HH)2\left(\theta^H v'\left(g_*^{HH}\right)-c'\left(g_*^{HH}\right)\right)=0\end{aligned} \tag{41}$$

from (28).

$$q = \begin{aligned} &\theta^L v\left(g_A^{L*}\right) - c\left(g_A^{L*}\right) - g_A^{L*}\left(\theta^L v'\left(g_A^{L*}\right) - c'\left(g_A^{L*}\right)\right) \\ &+\theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) - g_A^{H*}\left(\theta^H v'\left(g_A^{H*}\right) - c'\left(g_A^{H*}\right)\right) \\ &-\left(\begin{aligned} &\theta^L v\left(g_N^{L*}\right) - c\left(g_N^{L*}\right) - g_N^{L*}\left(\theta^L v'\left(g_N^{L*}\right) - c'\left(g_N^{L*}\right)\right) \\ &+\theta^H v\left(g_N^{H*}\right) - c\left(g_N^{H*}\right) - g_N^{H*}\left(\theta^H v'\left(g_N^{H*}\right) - c'\left(g_N^{H*}\right)\right) \end{aligned}\right) \end{aligned} \tag{42}$$

from (34) or (35) and

$$q = \begin{aligned} &2\left(\theta^H v\left(g_{A*}^{HH}\right) - c\left(g_{A*}^{HH}\right) - g_{A*}^{HH}\left(\theta^H v'\left(g_{A*}^{HH}\right) - c'\left(g_{A*}^{HH}\right)\right)\right) \\ &-2\left(\theta^H v\left(g_{N*}^{HH}\right) - c\left(g_{N*}^{HH}\right) - g_{N*}^{HH}\left(\theta^H v'\left(g_{N*}^{HH}\right) - c'\left(g_{N*}^{HH}\right)\right)\right) \end{aligned} \tag{43}$$

from (36). (6) admits the determination of the audit probabilities for $"LH","HL","HH"$, because, with $\gamma^*\left(LL\right)=0$, and positive Lagrangian multipliers $\mu_{LL,LH}, \mu_{LL,HL}, \mu_{LL,HH}$,

$$\gamma\left(LH\right)=\gamma\left(HL\right)=1-\frac{\left(g_{N*}^{LL}+g_{N*}^{LL}\right)}{\left(g_N^{L*}+g_N^{H*}\right)} \tag{44}$$

$$\gamma\left(HH\right)=1-\frac{\left(g_{N*}^{LL}+g_{N*}^{LL}\right)}{\left(g_{N*}^{HH}+g_{N*}^{HH}\right)} \tag{45}$$

The structure of the present model allows a mapping of results from Harris/Raviv (1998), if some additional notation is introduced and some additional assumptions are made:

Let $G_{LL}^*\left(q\right)=2g_{N*}^{LL}\left(q\right)$ denote the aggregated amount of the optimal values of the two public goods in state LL. Likewise, let $G_{LH}^*\left(q\right)=G_{HL}^*\left(q\right)=g_N^{L*}\left(q\right)+g_N^{H*}\left(q\right)$ denote this aggregate in the mixed states of the world LH and HL and $G_{HH}^*\left(q\right)=2g_{N*}^{HH}\left(q\right)$ be the aggregate for state HH.

Define $B_i\left(g_i\left(q\right),\theta_i\right)=\theta_i v\left(g_i\left(q\right)\right)-c\left(g_i\left(q\right)\right)$ as the net benefit the household receives from provision of public good i and $B_i'\left(g_i\left(q\right),\theta_i\right)=\frac{\partial B_i\left(.\right)}{\partial g_i}=\theta_i v'\left(g_i\left(q\right)\right)-c'\left(g_i\left(q\right)\right)$ as its derivative with respect to g_i. Now define[15]

$$\Omega\left(g_i\left(q\right),\theta_i\right)=B_i\left(g_i\left(q\right),\theta_i\right)-g_i\left(q\right)B'\left(g_i\left(q\right),\theta_i\right)$$

[15] This function is named $g\left(.\right)$ in Harris/Raviv (1998).

The following two assumptions with respect to $\Omega(\ )$ allow the derivation of global results in the information problem:

Assumption 1: $\Omega(\ )$ is convex and increasing in g , i.e. $\frac{\partial \Omega}{\partial g} \geq 0, \frac{\partial^2 \Omega}{\partial g^2} \geq 0$.

In terms of the net benefit function $B(g,\theta)$ this implies firstly that $-g_i(q)B''(g_i(q),\theta_i) \geq 0$ or that in terms of the elementary functions $\theta_i v''(g_i(q)) - c''(g_i(q)) \leq 0$ must hold in the relevant range. This will regularly be the case because of the second order conditions for a maximum.

Secondly, it must be the case that $-B''(g_i(q),\theta_i) - g_i(q)B'''(g_i(q),\theta_i) \geq 0$. In terms of the elementary functions this requires

$$-\left(\theta_i v''(g_i(q)) - c''(g_i(q))\right) - g_i(q)\left(\theta_i v'''(g_i(q)) - c'''(g_i(q))\right) \geq 0$$

The first part of this expression again will typically be positive from the second order conditions. The second part of the expression will allow a global analysis if $\theta_i v'''(g_i(q)) - c'''(g_i(q)) \leq 0$. Many numerical functions typically used in the analysis of the provision of public goods will preclude this from being the case. Especially the usual simplifying normalization of a constant marginal rate of transformation between public and private goods which results in $c''' = 0$ will disallow an informational analysis if it is used in conjunction with a typical Cobb-Douglas elementary utility function which results in $v''' > 0$. There exist however many combinations of concave utility functions and convex cost functions that allow the derivation of global results, because the condition holds.[16] One example is used later on to illustrate the result graphically and numerically, namely $v(g) = Ln(g)$ as an elementary utility function with a cubic cost function. The property also holds with the utility function $v(g) = -e^{-g}$ which is well known from the theory of uncertainty.[17], and sufficiently convex cost functions. However, these need not even be quadratic.[18]

Assumption 2: $\Omega(\ )$ is decreasing in θ , $\frac{\partial \Omega}{\partial \theta} < 0$.

In terms of the net benefit function $B(g,\theta)$ this necessitates that $\frac{\partial B_i(g_i(q),\theta_i)}{\partial \theta_i} - g_i(q)\frac{\partial B'(g_i(q),\theta_i)}{\partial \theta_i} < 0$.

[16] In many analyses of bureaucratic behavior, concave benefit functions and convex cost functions for public goods at public agencies are routinely assumed. See e.g. the respective chapter in Mueller (2003).

[17] This function is used e.g. by Nielsen (1998).

[18] Another class of utility functions which exhibits this property, is $v(g) = g^{\theta}$, which ,however, is different from the multiplicative notation employed in the present analysis.

With respect to the underlying elementary functions, as we have introduced them,[19] it demands

$$\frac{\partial\left(\theta_i v\left(g_i(q)\right)-c\left(g_i(q)\right)\right)}{\partial\theta_i}-g_i(q)\frac{\partial\left(\theta_i v'\left(g_i(q)\right)-c'\left(g_i(q)\right)\right)}{\partial\theta_i}<0 \tag{46}$$

$\Leftrightarrow$

$v\left(g_i(q)\right)-g_i(q)v'\left(g_i(q)\right)<0$.[20]

This can be reformulated in an elasticity expression as the requirement that

$$v\left(g_i(q)\right)\left(1-\frac{\partial v\left(g_i(q)\right)}{\partial g_i(q)}\frac{g_i(q)}{v\left(g_i(q)\right)}\right)<0,$$

i.e. the elasticity of the elementary utility function with respect to the level of the public good supplied must be less than unity.[21] Generally, (46) illustrates the general requirement that has to be satisfied by the net benefit function and its derivative, if the global results to be presented are to be applicable. This specificity with respect to functional forms is not uncommon in analysis where there is a combination of informational problems with other economic aspects.[22]

Let us now turn to the optimal solution of the problem of the government. We will rely on the results derived in Harris/Raviv (1998). It is our purpose to illustrate in the process the importance of the assumptions made above for the validity of the solution and demonstrate how a weakening of the assumptions can accommodate a broader applicability of the results.

Due to the nature of the problem it is to be expected that an increase in the cost of auditing will decrease its value. Just as no auditing is optimal if it does bring no benefit (i.e. in the case of no informational asymmetries above), it will be of less value of the costs of performing an audit are high compared to the benefits for the government. The main benefit of the possibility of an audit is to deter an agency decision maker from misrepresenting, that is overstating his case.[23] This allows the government to provide for a larger supply of public goods compared to a situation where no audit was possible and hence there could be no discrimination between the different states of the world.

---

[19] It is a possibility for future research to analyze the problem in the context of type-dependent cost functions as in Boadway/Horiba/Jha (1999). However, as they have demonstrated, the often used single-crossing property need not hold in such a setting.

[20] This simple form is caused by the way we have modeled the influence of the type parameter. Only if it is introduced in the simple multiplicative form will the requirement take this expression. If the type parameter is introduced in a more complicated form in the utility function, this will no longer be the case. Then more elementary utility functions are admissible.

[21] This property is more restrictive as a multiplicative type parameter is employed. If the type parameter was introduced in a more general way, this problem would be less severe. In section 4, a numerical function is used that exhibits this property in the relevant range.

[22] Compare e.g. Dhillon/Perroni/Scharf (1999).

[23] In this respect the problem is related to the traditional analysis of tax evasion. The two main differences are that firstly the agent under consideration is a government agent and secondly that he does want to overstate his case (get larger public facilities) whereas a typical tax evader is understating his case, i.e. his taxable income.

Because of the structural isomorphism, the solution concept of Harris/Raviv (1998) applies. The optimal solution for the values of the public facilities when no audit is going to be performed

$$g_{N*}^{LL}(q),\ g_{N}^{L*}(q),\ g_{N}^{H*}(q),\ g_{N*}^{HH}(q),\ \gamma(LL)=0\ ,\ \gamma(LH)=\gamma(HL)=1-\frac{2g_{N*}^{LL}(q)}{g_{N}^{L*}(q)+g_{N}^{H*}}$$ and

$$\gamma(HH)=1-\frac{g_{N*}^{LL}(q)}{g_{N*}^{HH}(q)}$$

allows the partition of the real line measuring the auditing cost q into three intervals. In each interval, a different subset of the first order conditions derived above has to hold.

For $q\in(0,q_2)$, the first order conditions to determine the optimal amounts $\left(g_{N*}^{LL}(q),g_{N}^{L*}(q),g_{N}^{H*}(q),g_{N*}^{HH}(q)\right)$ are (38)-(43). The two messages $"LH"$ and $"HL"$ are audited with the probability determined by (44) and $"HH"$ is audited with the probability according to (45). The intuition for this is that with small auditing costs it is worthwhile for the government to discriminate between the mixed states and the "bad pure" state LL, even though the utility differential between these states is likely to be small compared to the difference between LL and HH, which is the reason that there is also an incentive to discriminate between these two states of the world.

If the audit costs are as high as q_2, the optimal aggregate $g_{N}^{L*}(q_2)+g_{N}^{H*}(q_2)=2g_{N*}^{LL}(q_2)$ for $"LH"$ or $"HL"$ will be set equal to the optimal aggregate level for $"LL"$ and consequently the optimal auditing probability for these two messages drops to zero according to(44). The intuition for this is that the possible gains in utility from discriminating between the mixed states and the bad state of the world no longer suffice to compensate the household for the possible expenditure on auditing costs. The differentiation between these states and the situation in HH is yet worthwhile.

For $q\in[q_2,q_3)$, the first order conditions which determine the optimal budgets are (38)-(41) and (43). The total budget will be identical for the three messages $"LL","LH","HL"$ which will never be audited. The optimal probability to audit message $"HH"$ is determined by (45).

If q is as high as q_3, the audit probability for $"HH"$ also goes to zero (45), because the agency will get the same budget and size of public facilities, no matter what message it sends, $2g_{N*}^{LL}(q)=g_{N}^{L*}(q)+g_{N}^{H*}=2g_{N*}^{HH}(q)=2\overline{g}$, where $2\overline{g}$ denotes the solution to the simple expected utility maximization problem of the government which maximizes ex ante utility without informational concerns.

Proposition 3:

The optimal solution has the following properties[24]

1. $0 < q_2 < q_3$

2. $g_N^{L*}(q) < \frac{g_N^{H*}(q)}{2} < g_N^{H*}(q) - g_N^{L*}(q), \forall q$

3. (a) If auditing costs are in the interval $(0, q_2)$, $g_{N*}^{LL}(q)$ the optimal amount in the worst state increases with q whereas all other allocations $\left(g_N^{H*}(q), g_N^{L*}(q), g_{N*}^{HH}(q)\right)$ decrease. (b) If auditing costs are in the interval $[q_2, q_3)$, the budget allocation $g_{N*}^{HH}(q)$ decreases, whereas $2g_{N*}^{LL}(q) = g_N^{L*}(q) + g_N^{H*}(q)$ and also $g_N^{L*}(q)$ and $g_{N*}^{H}(q)$ increase. (c) If auditing costs are higher than $q_3, q > q_3$, allocated budgets do not depend on q and all aggregate budgets are identical, $2g_{N*}^{LL}(q) = g_N^{L*}(q) + g_N^{H*}(q) = 2_{N*}^{HH}(q) = 2\overline{g}$.

4. If auditing costs are zero, the first best allocation can be implemented. This implies $g_{N*}^{LL}(0) = g_A^{L*}, g_N^{L*}(0) = g_A^{L*}, g_N^{H*}(0) = g_A^{H*}, g_{N*}^{HH}(0) = g^H*, \underline{g}(0) = g_A^{H*}$. If auditing costs are positive, $g_N^{L*}(q) > 2g_A^{L*}, \forall q > 0$. $g_N^{L*}(q) + g_N^{H*}(q) < g_A^{L*} + g_A^{H*}$, if $q \le q_2$ and $g_{N*}^{HH}(q) < g_A^{H*}, \forall q > 0$.

5. (a) If $q \in (0, q_2)$, $2g_{N*}^{LL}(q) < g_N^{L*}(q) + g_N^{H*}(q) < 2g_{N*}^{HH}(q)$.

   (b) If $q \in [q_2, q_3)$, $2g_{N*}^{LL}(q) = g_N^{L*}(q) + g_N^{H*}(q) < 2g_{N*}^{HH}(q)$

6. $\gamma(LH, q) = \gamma(HL, q)$ decreases for $q \in (0, q_2)$. $\gamma(LH, q_2) = \gamma(HL, q_2) \equiv 0$ and for higher q. $\gamma(HH, q) > \gamma(LH, q)$ decreases in q and $\gamma(HH, q_3) \equiv 0$ for higher q.

The proof of the proposition consists of demonstrating that the first-order conditions of the problem of the government hold for the solution, provided assumptions A1 and A2 are fulfilled and to confirm that the presumption that only the incentive compatibility constraints for the type LL holds at the solution, is valid.

Proof: [25]

1. $0 < q_2 < q_3$

[24] Cf. Harris/Raviv (1998).

[25] Cf. Harris/Raviv (1998).

a.) Suppose that $q_2 \le 0$. Then for positive audit probabilities using the notation introduced above and the definition of the $\Omega(\ )$-function, (42) reads[26]

$$q = \theta^L v\left(g_A^{L*}\right) - c\left(g_A^{L*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right)$$
$$-\Omega\left(g_N^{L*}(q)\right) - \Omega\left(G_{LH}(q) - g_N^{L*}(q)\right) \qquad < 0$$

Because by assumption A1 $\Omega(g)$ is increasing in g, this implies $g_N^{L*}(q) > g_A^{L*}$ und $g_N^{H*} = G_{LH}(q) - g_N^{L*}(g) > g_A^{H*}$. By definition of q_2, it is the case that $G_{LL}(q_2) = G_{LH}(q_2)$ and hence $G_{LH}(q_2) \ge g_A^{L*} + g_A^{L*} > 2g_{A*}^{LL}$. At the same time, (43) has to hold,

$$q_2 = 2\left(\theta^H v\left(g_{A*}^{HH}\right) - c\left(g_{A*}^{HH}\right) - \Omega\left(\frac{G_{HH}(q_2)}{2}\right)\right) < 0$$

which implies $G_{HH}(q_2) = 2g_{N*}^{HH} > 2g_{A*}^{HH}$. These three allocations however clearly violate (41). Therefore q_2 must be greater than zero.

On the other hand, suppose $q_2 > q_3$. Using again (43) which must hold for both q_3 and q_3 leads to $\frac{G_{HH}(q_2)}{2} = g_{N*}^{HH}(q_2) < \frac{G_{HH}(q_3)}{2} = g_{N*}^{HH}(q_3)$.[27] If this would also hold for the allocation in state LL, $\frac{G_{LL}(q_2)}{2} = g_{N*}^{LL}(q_2) < \frac{G_{LL}(q_3)}{2} = g_{N*}^{LL}(q_3)$, because of the definition of q_2, $G_{LL}(q_2) = G_{LH}(q_2) = G_{HL}(q_2)$, and the optimal composition of the public goods in the mixed states, it would follow that $g_N^{L*}(q_2) \le g_N^{L*}(q_3)$ and

$G_{LH}(q_2) - g_N^{L*}(q_2) = g_N^{H*}(q_2) \le G_{LH}(q_3) - g_N^{L*}(q_3) = g_N^{L*}(q_3)$. This however would violate (41) at either q_2 or q_3. Hence $\frac{G_{LL}(q_2)}{2} \ge \frac{G_{LL}(q_3)}{2}$.

---

[26] Recall that by definition

$$\Omega\left(g_A^{i*}, \theta^i\right) = \theta^i v\left(g_A^{i*}\right) - c\left(g_A^{i*}\right) - g_A^{i*}\left(\theta^i v'\left(g_A^{i*}\right) - c'\left(g_A^{i*}\right)\right)$$
$$= \theta^i v\left(g_A^{i*}\right) - c\left(g_A^{i*}\right),\ i = L, H \qquad .$$

[27] Because q_2 is larger less must be subtracted from the maximal value of the net benefit, hence with $\Omega(\ )$ rising in g this can hold only for a smaller size of the public facilities.

Then $G_{LH}(q_2) = G_{LL}(q_2) \geq G_{LH}(q_3) = G_{LL}(q_3)$ follows. Furthermore, this implies $g_N^{L*}(q_2) > g_N^{L*}(q_3)$ and $G_{LH}(q_2) - g_N^{L*}(q_2) = g_N^{H*}(q_2) > G_{LH}(q_3) - g_N^{L*}(q_3) = g_N^{L*}(q_3)$. Then (42) leads to

$$
\begin{aligned}
q_2 &= \theta^L v\left(g_A^{L*}\right) - c\left(g_A^{L*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - \Omega\left(g_N^{L*}(q_2), \theta^L\right) - \Omega\left(G_{LH}(q_2) - g_N^{L*}(q_2), \theta^H\right) \\
&\leq \theta^L v\left(g_A^{L*}\right) - c\left(g_A^{L*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - \Omega\left(g_N^{L*}(q_3), \theta^L\right) - \Omega\left(G_{LH}(q_3) - g_N^{L*}(q_3), \theta^H\right) \\
&\leq \theta^L v\left(g_A^{L*}\right) - c\left(g_A^{L*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - \Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^L\right) - \Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^H\right) \\
&< \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - -\Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^L\right) - \Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^H\right) \\
&< \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - -\Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^H\right) - \Omega\left(\frac{G_{LH}(q_3)}{2}, \theta^H\right) \\
&= \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) + \theta^H v\left(g_A^{H*}\right) - c\left(g_A^{H*}\right) \\
&\quad - -\Omega\left(\frac{G_{HH}(q_3)}{2}, \theta^H\right) - \Omega\left(\frac{G_{HH}(q_3)}{2}, \theta^H\right) \\
&= q_3
\end{aligned}
$$

which contradicts the assumption. The first weak inequality stems from the fact that $G_{LH}(q_2) \leq G_{LH}(q_3)$. The second weak inequality results from assumption A1, weak convexity of the $\Omega(\ )$ function. The first inequality results from the fact that maximum benefits increase in θ. The second inequality is caused by assumption A2, $\Omega_\theta < 0$. The final equalities are the result of the definition of q_3, $G_{LH}(q_3) = G_{HH}(q_3)$ and optimality condition (43).

This extended argument demonstrates that the assumptions of Harris/Raviv (1998) are too restrictive and thus that the applicability of the result can be broadened. The assumption that $\Omega_\theta < 0$ is only needed to the extend that the result can hold in numerical structures even when this general assumption is not satisfied.

2. $g_N^{L*}(q) < \dfrac{g_N^{H*}(q)}{2} < g_N^{H*}(q) - g_N^{L*}(q), \forall q$

The second condition follows firstly from the optimal expenditure mix on the public goods in the mixed states of the world, (38) and (39). Secondly, because the elementary net benefit $\theta v(g)-c(g)$ is increasing in θ:

$$\begin{aligned}
&B'\left(g_N^{L*}(q),\theta^L\right)=B'\left(G_{LH}(q)-g_N^{L*}(q),\theta^H\right)\\
&\Rightarrow g_N^{L*}(q)<G_{LH}(q)-g_N^{L*}(q)\\
&\Rightarrow g_N^{L*}(q)<\frac{G_{LH}(q)}{2}\\
&\Rightarrow G_{LH}(q)-g_N^{L*}(q)=g_N^{H*}>\frac{1}{2}
\end{aligned}$$

3. (a) If auditing costs are in the interval $(0,q_2)$, $g_{N*}^{LL}(q)$ the optimal amount in the worst state increases with q whereas all other allocations $\left(g_N^{H*}(q),g_N^{L*}(q),g_{N*}^{HH}(q)\right)$ decrease.

(b) If auditing costs are in the interval $[q_2,q_3)$, the budget allocation $g_{N*}^{HH}(q)$ decreases, whereas $2g_{N*}^{LL}(q)=g_N^{L*}(q)+g_N^{H*}(q)$ and also $g_N^{L*}(q)$ and $g_{N*}^{H}(q)$ increase.

(c) If auditing costs are higher than $q_3, q>q_3$, allocated budgets do not depend on q and all aggregate budgets are identical, $2g_{N*}^{LL}(q)=g_N^{L*}(q)+g_N^{H*}(q)=2_{N*}^{HH}(q)$.

This element of the proposition has three parts.

For the first part, (42) was already used to for the effect that an increase in q necessitates a smaller value of the Ω function terms on the right hand side, which can only be achieved with a smaller value of the respective public goods. The same effect works through (43) if this condition has to hold. Thus $g_{N*}^{HH}(q)$ declines, if $q<q_3$. Additionally, the optimal mix of public goods in the mixed states forces a co-movement of the respective public goods levels. Hence $g_N^{L*}(q),g_N^{H*}(q),G_{LH}(q)$ always move in the same direction. For $q<q_2$ therefore, these three values decline. The dependence of $G_{LL}(q)=2g_{N*}^{LL}(q)$ on q is therefore determined by (41). For $(0,q_2)$, all other variables decline, rising the value of their respective terms in this condition. Hence it can only continue hold if the first term becomes negative. This implies that $G_{LL}(q)$ must rise continually on the interval.

If auditing costs q become as high as q_2 in the second part, $G_{LH}(q_2)=G_{LL}(q_2)$ results. Thus $g_N^{L*}(q),g_N^{H*}(q),G_{LH}(q)$ and $g_{N*}^{LL}(q)$ depend on q in the same way. Now, because $g_{N*}^{HH}(q)$ still declines up until q is as high as q_3, (41) necessitates an increase in the size of public facilities in all other states of the world.

Suppose to the contrary that there exist two values of $q > q_3$, $q_A > q_B > q_3$, where the condition does not hold. Let $G_{LH}(q_A) > G_{LH}(q_B)$ hold. The optimal mix of public facilities then results in $g_N^{L*}(q_A) > g_N^{L*}(q_B)$ and $g_N^{H*}(q_A) > g_N^{H*}(q_B)$. Because these values evolve in the same direction, (41) would be violated at either q_A or q_B. Hence no such values q_A or q_B $> q_3$ can exist..

4. (a) If auditing costs are zero, the first best allocation can be implemented. This implies $g_{N*}^{LL}(0) = g_A^{L*}, g_N^{L*}(0) = g_A^{L*}, g_N^{H*}(0) = g_A^{H*}, g_{N*}^{HH}(0) = g^H*, \underline{g}(0) = g_A^{H*}$.

(b) If auditing costs are positive,

$g_N^{L*}(q) > g_A^{L*}, \forall q > 0$. $g_N^{L*}(q) + g_N^{H*}(q) < g_A^{L*} + g_A^{H*}$, if $q \leq q_2$ and $g_{N*}^{HH}(q) < g_A^{H*}, \forall q > 0$.

This part of the proposition has two parts. Part (a) is easily proved by plugging $q = 0$ into (42) and (43). The left hand sides of these expressions become zero only of the first-best optimal values for the public goods are selected, because (38) and (39) again force an optimal mix of public goods. The probabilities calculated from these values according to (44) and (45) are the minimal auditing probabilities necessary to enforce the truthful reporting by types LL, LH and HL. Part (b) results from the previous elements of the proposition, starting from the first best values at $q = 0$. Part 3(a) results in the increase of $g_{N*}^{LL}(q)$ above its first best level for all q. That $g_N^{L*}(q) + g_N^{H*}(q)$ decrease until $q = q_2$, is also pertinent to 3(a). Starting from a first best level, this implies that the actual levels for positive auditing costs are smaller. This holds at least until a level of $q = q_2$, because for higher levels of q the increase of the allocation might lead up to a level greater or smaller than the first best.[28] That $g_{N*}^{HH}(q) < g_A^{H*}, \forall q > 0$ is not surprising given that g_{N*}^{HH} monotonically falls over the interval $(0, q_3)$. If q is higher still, the level of the public goods becomes independent of q, namely it becomes equal to the unmodified value $2\overline{g}$ that maximizes the expected utility of the household. If auditing costs are too high, it is no longer worthwhile to try discriminate between the different states of the world by threatening the agency decision maker with a possible probability of an audit.

5. (a) If $q \in (0, q_2)$, $2g_{N*}^{LL}(q) < g_N^{L*}(q) + g_N^{H*}(q) < 2g_{N*}^{HH}(q)$.

(b) If $q \in [q_2, q_3)$, $2g_{N*}^{LL}(q) = g_N^{L*}(q) + g_N^{H*}(q) < 2g_{N*}^{HH}(q)$

This part of the proposition also follows in large parts from previous parts. At $q = 0$ the first best values are implemented, for which the condition holds trivially. At $q = q_2$

[28] The numerical example in section 4 exhibits this property. The overall likelihood of such a result depends on the actual importance of screening the state HH. The more important the utility gain in this state compared to the other states in the expected utility calculus, the more likely is this result.

$2g_{N*}^{LL}(q_2) = g_N^{L*}(q_2) + g_N^{H*}(q_2)$ and both allocations rise respectively decrease monotonically over the interval. Hence the first part of (a) holds. The second part of (a) holds because on $[0, q_2)$ both the mixed types and type HH are audited with positive probability. Hence (42) and (43) must be equalized. Thus

$$\theta^H v(g_{A*}^{HH}) - c(g_{A*}^{HH}) + \theta^H v(g_{A*}^{HH}) - c(g_{A*}^{HH}) - \Omega\left(\frac{G_{HH}(q)}{2}\right) - \Omega\left(\frac{G_{HH}(q)}{2}\right)$$
$$=$$
$$q$$
$$=$$
$$\theta^H v(g_A^{H*}) - c(g_A^{H*}) + \theta^L v(g_A^{L*}) - c(g_A^{L*}) - \Omega(g_N^{L*}(q), \theta^L) - \Omega(G_{LH}(q) - g_N^{L*}(q), \theta^H)$$

which can be written as

$$\theta^H v(g_{A*}^{HH}) - c(g_{A*}^{HH}) + \theta^H v(g_{A*}^{HH}) - c(g_{A*}^{HH})$$
$$-(\theta^H v(g_A^{H*}) - c(g_A^{H*})) - (\theta^L v(g_A^{L*}) - c(g_A^{L*}))$$
$$=$$
$$\Omega\left(\frac{G_{HH}(q)}{2}\right) + \Omega\left(\frac{G_{HH}(q)}{2}\right)$$
$$-\Omega(g_N^{L*}(q), \theta^L) - \Omega(G_{LH}(q) - g_N^{L*}(q), \theta^H)$$

The left hand side of this equation is clearly positive, namely $\theta^H v(g_{A*}^{HH}) - c(g_{A*}^{HH}) - (\theta^L v(g_A^{L*}) - c(g_A^{L*})) > 0$. If $G_{LH}(q) = G_{HH}(q)$ anywhere on $[0, q_2)$, which would be necessary to invalidate the statement, at this value of q,

$$\Omega\left(\frac{G_{LH}(q)}{2}\right) + \Omega\left(\frac{G_{LH}(q)}{2}\right) - \Omega(g_N^{L*}(q), \theta^L) - \Omega(G_{LH}(q) - g_N^{L*}(q), \theta^H) \le 0,$$

a contradiction. Given that the right hand side will be positive for regular public goods problems, it follows that the assumption about the convexity of the $\Omega(\ )$ function is necessary only for the result to hold in general. Weak convexity, which would make the right hand side equal to zero would be sufficient to generate a general result. For numerical structures or concrete numerical functional forms which are not entirely uncommon in the analysis of uncertainty, this condition could be checked for any given structure. Whenever the property holds over the relevant range of values, the basic assumption is unnecessary restrictive.

The second part follows from the fact that $2g_{N*}^{LL}(q_2) = g_N^{L*}(q_2) + q_N^H(q_2)$, continuity of the functions and $2g_{N*}^{LL}(q_3) = g_N^{L*}(q_3) + q_N^H(q_3) = 2g_{N*}^{HH}(q_3)$, using an equivalent logic as in the first part. The key to the result is again the interaction between the different first order conditions which apply, given that $\gamma(HH) > 0$ over the interval.

If $q \geq q_3$, the optimal allocation for all states of the world will be the one that would be implemented in a standard expected utility maximization calculus. The reason for this is that because of the high auditing costs the possibility to discriminate between different states of the world is no longer worthwhile from the point of view of the welfare maximizing government. Hence it defaults to a standard situation as if there were no ex post possibility to adapt the supply of public goods to the realized state of the world. The solution to this problem are then just the standard expected utility maximizing values of g_1 and g_2.

6. $\gamma(LH,q) = \gamma(HL,q)$ decreases for $q \in (0,q_2)$. $\gamma(LH,q_2) = \gamma(HL,q_2) \equiv 0$ and for higher q. $\gamma(HH,q) > \gamma(LH,q)$ decreases in q and $\gamma(HH,q_3) \equiv 0$ for higher q.

These properties can be calculated by plugging the results from the previous parts of the proposition about the development of the amounts of the public goods $g_{N*}^{LL}, g_N^{L*}, g_N^{H*}, g_{N*}^{HH}$ into the determining equations (43) and (44).

The results above are derived on the basis of the assumption that only the incentive compatibility constraints of type LL agency bind at the optimum. This seems intuitively plausible given that the audit probabilities are calculated such that type LL which has the most to gain from mimicking **any** of the other types and especially the best type HH, because that typegets the biggest allocations of public goods. Hence the audit probability $\gamma(HH)$ will also deter types LH and HL from mimicking type HH, because they have less to gain from this than LL. This is checked in the following way:

If one substitutes the results into the incentive compatibility constraint (6) of type LL, one gets

$$+\mu_{LL,LH} b(L)\{0\}$$
$$+\mu_{LL,HL} b(L)\{0\}$$
$$+\mu_{LL,HH} b(L)\{0\}$$

after factoring out $b(L)$. Hence the constraints for type LL are binding.

Substitution into the incentive compatibility constraint (7) of type LH results in 3 expressions which we will analyze in turn. Using the notation introduced above, the constraint versus type LL reads

$$\mu_{LH,LL}\left\{\begin{array}{l}\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_N^{L*}+b(H)\left(G_{LH}-g_N^{L*}\right)\right)+\left(1-\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_{A*}^{LL}+b(H)g_{A*}^{HH}\right)\\-\left(b(L)\frac{G_{LL}}{2}+b(H)\frac{G_{LL}}{2}\right)\end{array}\right\}$$

As long as type LH gets another allocation than type LL we know from above that $g_{A*}^{LL}+g_{A*}^{HH}>G_{LH}>G_{LL}$. Because the allocation without an audit is optimal with respect to the relative importance of the two public goods in the utility function of the representative household, the first term exhibits the following property:

$$\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_N^{L*}+b(H)\left(G_{LH}-g_N^{L*}\right)\right)>\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)\frac{G_{LH}}{2}+b(H)\frac{G_{LH}}{2}\right)$$
$$=\frac{G_{LL}}{2}\left(b(L)+b(H)\right)$$

Therefore, as long as $G_{LH}>G_{LL}$, the constraint versus type LL is not binding and hence $\mu_{LH,LL}$ must be zero. Examining the constraint versus type HL,

$$+\mu_{LH,HL}\left\{\begin{array}{l}\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_N^{L*}+b(H)\left(G_{LH}-g_N^{L*}\right)\right)+\left(1-\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_{A*}^{LL}+b(H)g_{A*}^{HH}\right)\\-\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)\left(G_{LH}-g_N^{L*}\right)+b(H)g_N^{L*}\right)\end{array}\right\}$$

The expression in brackets will be positive for the solution obtained as long as $b(H)-b(L)>0$ which holds by assumption. The critical part of the incentive compatibility constraint is the relationship between type LH (and HL) and type HH, which given the solution would provide an LH-decision maker with a higher level of utility, because the aggregate size of the facilities will be larger in state HH.

$$+\mu_{LH,HH}\left\{\begin{array}{l}\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_N^{L*}+b(H)\left(G_{LH}-g_N^{L*}\right)\right)+\left(1-\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_{A*}^{LL}+b(H)g_{A*}^{HH}\right)\\-\left(\frac{G_{LL}}{G_{HH}}\right)\left(b(L)g_{N*}^{HH}+b(H)g_{N*}^{HH}\right)\end{array}\right\}$$

With $G_{HH}=2g_{N*}^{HH}$ and because of convexity for $G_{LH}\geq G_{LL}$ and the optimal mix of the public goods the first part of the expression will have

$$\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)g_N^{L*}+b(H)\left(G_{LH}-g_N^{L*}\right)\right)\geq\left(\frac{G_{LL}}{G_{LH}}\right)\left(b(L)\frac{G_{LH}}{2}+b(H)\frac{G_{LH}}{2}\right)$$
$$=\frac{G_{LL}}{2}\left(b(L)+b(H)\right).$$

Hence for $G_{LH} > G_{LL}$, type LH (and analogously type HL) will have no incentive to mimick any of the other types.

Type HH will get the largest allocation of public goods and therefore trivially has no incentive to try to mimick either a mixed type or type LL, which get a smaller allocation of the public goods.

Overall the solution described by the proposition has many intuitively plausible elements. The general effect of higher auditing costs which have to be balanced against possible utility gains from discriminating between different states of the world is to reduce the possible welfare gains from discrimination. In contrast to many standard applications, the optimal supply of public goods in the good state of the world HH will be distorted downwards from the first best. The reason for this is that a balance has to be struck between a higher supply of public goods and the resulting informational rents which have to be optimally granted to the other types (states of the world) given the preferences of the decision maker of the public agency.

We will illustrate the solution to the provision of public goods under budgeting with the following example which exhibits the necessary properties:

$U = Y + \theta_1 Ln(g_1) + \theta_2 Ln(g_2) - g_1^3 - g_2^3$

and $\theta_i \in \{3,6\}, i = 1,2$, i.e. $\theta^L = 3, \theta^H = 6$.

The first best value for the realisation θ^L is then $g_{A*}^{LL} = g_A^{L*} = 1$ and for θ^H it is $g_{A*}^{HH} = g_A^{H*} = 2^{1/3}$. Both required properties, i.e. Assumptions A1 and A2 hold for values of the public goods not too close to zero and not to distant from Euler's e. Let the endowment be $Y = 10$.

The following table presents the results for this example for values of the audit cost varying from approximately zero to q_3.

Table 1 about here

For the example chosen with no audit costs the implied audit probabilities are $\gamma(HH,0) = .206299$ whereas the message "LH" would be audited with the probability $\gamma(LH,0) = 0.115012$. Although one would expect the audits to be conducted with probability 1 as they do not cause any costs, those two values are the minimal probabilities necessary to generate the incentive effects to deter misrepresentation by type LL. The optimal allocations of public goods given $q = 0$ are the first best ones, as can be seen from table 1 with $G_{LL} = 2 = 2g_{N*}^{LL}$ implying $g_{N*}^{LL} = g_{A*}^{LL} = 1$. $G_{LH} = g_N^{L*} + g_N^{H*} = 1 + 2^{1/3}$ and the agency will set $g_N^{L*} = g_A^{L*} = 1$ and

$g_N^{H*} = g_A^{H*} = 2^{1/3}$. Finally $G_{HH} = 2 \cdot 2^{1/3} = 2g_{N*}^{HH}$ such that $g_{N*}^{HH} = g_{A*}^{HH} = 2^{1/3}$ will be set by the agency.

The data are represented in the following two figures, to illustrate properties 4 through 6 of the optimal solution to the mechanism design problem of the government. From table 1 it is evident that the two threshold values for the audit costs are $q_2 \approx 0.6895$ and $q_3 \approx 1.442$.

In figure 1, the aggregate supplies of the two public goods are plotted against the audit costs. The dotted line denotes the aggregate level G_{LL} in the bad state of the world. The dashed line denotes the total allocation in the intermediate states of the world G_{LH} and G_{HL}. Finally the full line depicts the total allocation in the good state of the world G_{HH}.

Figure 1 here

The aggregate supply of public goods in all states of the world starts at the first best value. The increase in audit costs leads to a decrease in those states of the world where at least one valuation is high. Correspondingly the audit probabilities decrease. The intuition for this result is that the agency head who has realised the worst state of the world LL achieves an informational rent, because his ability to mimick a better state of the world, i.e. send a wrong signal to the government about the realised state of the preference intensities, must be rewarded by a higher total of public goods to induce him to truth-telling. These costs have to be balanced against the audit costs and as those increase the direct negative effects of the informational rent paid out to LL are reduced.

The downside of this informational rent is that the levels of public goods in the other states of the world have to be reduced. If they were kept at the initial level, informational rents received in the bad state of the world would have to be increased even further. Consequently the welfare possible by having high valuations for the public goods is reduced, because the aggregate supplies of these goods will fall short of the first best values. They will be further from these values the higher the audit costs facing the government are becoming.

If audit costs are as high as the threshold value q_2, it is no longer worthwhile for the government to discriminate between the bad state of the world LL and the two intermediate states of the world LH and HL. Given that the expenditure preferences of the agency head are aligned with the representative household, the optimal mix in the intermediate state of the world will be efficient (by (38) and (39)), even though the level of the expenditures will be below the first best.

If audit costs are too high, aggregate levels of the public goods will be equal in all states of the world. They will be higher than their first best value in the bad state of the world and lower in all three other states of the world. The government therefore has to cope with the informational asymmetries in two ways. First, it accepts welfare losses, because in those states of the world where at least one realised valuation is low the aggregate supply of public goods will be too high, resulting in waste in the public sector from the perspective of the representative household, but this is necessary given the informational advantage of the agency. In the good state of the world HH the aggregate supply of public goods is below the first best level, because it is not worthwhile to provide this level, given that with all aggregates identical this would also be provided in the other states of the world.

Depending on the intensity of the preferences it is also possible that the aggregate supply in the non-discriminating range of audit costs above q_3, will be above the first-best level for the intermediate state of the world. This happens in the present numerical case where the aggregate supply for (LL, HL, LH) in the interval $[q_2, q_3)$ rises above the first best level for the intermediate states. The reason for this is the high value attached to the public goods in the good state of the world HH, which makes it worthwhile to have such an overprovision not only relative to the first best of the bad state but also for the two intermediate states of the world.

Figure 2 here

Figure 2 depicts the development of the optimal audit probabilities which are determined according to (44) and (45) as long as they are positive. If these conditions would necessitate a negative value for the audit probabilities, they become zero as the relevant conditions change because of the complementary Kuhn-Tucker conditions. The dotted line depicts the audit probabilities for the intermediate states of the world (LH, HL) and the full line represents the audit probabilities for the message that the good state of the world HH has been realised. Both audit probabilities decrease continuously in the level of the audit costs facing the government. Once the audit probability for the intermediate states of the world has dropped to zero it stays there. This happens at the threshold value of $q = q_2$. The initial conditions would stipulate for higher values of q that the total supply of public goods would be lower in the intermediate states of the world than in the bad state of the world which would not make sense as then the intermediate states of the world would not be revealed as such but the agency would always send the message that the bad state of the world has been realised which leads to a higher aggregate level of public goods which can be provided in such a fashion that a higher level of utility for the agency head is possible.

The mechanism presented as such may also be subjected to the charge levelled above against competing mechanisms to provide information for public decision making that pure relevation mechanisms are rarely observed in practice. However, budgeting mechanisms which limit to some degrees the expenditure competencies of public officials are very often seen in reality. Most governments have to present budgets which have to be passed by legislative bodies before they are enabled to spend money. The recurring budget crises in the USA during the nineties when last minute negotiations between the president and the Congress repeatedly narrowly although not on all occasions avoided government shutdowns illustrate that argument

If the initial budgets are not sufficient, it is necessary to get approval for additional funds from the authority which is also in charge of allocating the initial budget, although such ex ante approval for additional expenditures is not always legally necessary if the expenditure authority can ex post prove that the budget overrun was necessitated by actual circumstances.

These examples from reality are easily transformed into a budget mechanism with rules for the application of money that is equivalent to the formal revelation mechanism developed above.[29]

In such a budget mechanism the agency receives as a base allocation of public goods the level of public goods to be provided in the bad state of the world, $G_{LL}(q)$ which is optimal according to the revealing mechanism developed above, given the audit cost q that the government faces. The agency is forced to provide equal amounts of the two public goods given this total.

If the agency wants to provide more public goods it has to apply for an increase in the allocation. It can either apply for $G_{LH} = G_{HL} = g_A^{L*} + g_A^{H*}$, that is the optimal (first best) allocation for the intermediate states of the world, or for $G_{A*}^{HH} = 2g_{A*}^{HH}$, the optimal allocation for the good state of the world.

The optimal reaction of the government to these requests depends on the level of audit costs q that it faces. First of all it can decide whether and to what extend the application is granted, depending on whether an audit is performed and it can mandate how the allocated public goods are to be divided between the two public goods.

If the head of the agency asks for G_{A*}^{HH}, which he will do only if that is the true state of the world, the allocation depends on whether an audit was performed or not. If no audit is performed, he does not receive the amount requested but only the amount that is optimal, given q, $G_{HH}(q)$. He is, however, forced to provide equal amounts of both public goods, i.e. to split the allocation evenly. If an audit is performed he receives "nothing", which means he is dismissed and receives only his reservation utility, if he is caught lying. If he told the truth, he receives the requested allocation and is also under the obligation to provide equal amounts of the two public goods. Naturally, to have the equivalence between this mechanism and the revealing mechanism, audits will only be performed as long as $q < q_3$. If audit costs are too high, no audit can take place and the only possible allocation that the government will sanction is the initial allocation $G_{LL}(q) = G_{LH}(q) = G_{HL}(q) = G_{HH}(q)$ for audit costs $q \geq q_3$.

If the decision maker asks for the allocation optimal for an intermediate state of the world, the response of the government also depends on the level of the audit costs. If $q \geq q_2$, no audits will take place and no increases will be sanctioned above the initial level $G_{LH}(q) = G_{HL}(q) = G_{LL}(q)$. However, the government does not need to know, for which public good realised preferences are high, because the preferences of the decision maker concerning the expenditure mix are in line with those of the representative household. Therefore the decision on the mix of the public goods can be delegated to the agency without causing any problems.

[29] Cf. also Harris/Raviv (1998).

If audit costs are low enough that positive audit probabilities $\gamma(LH,q)=\gamma(HL,q)>0$ in the revealing mechanism are feasible, the government will grant the allocation $G_{LH}(q)=G_{HL}(q)$ in case it decides not to perform an audit of the agency. If it performs an audit, it will again grant the request, as it discovers that the agency told the truth and realise the first best allocation of public goods for this state of the world.

To prevent a LL-agency from mimicking the intermediate case, the government has to include rules concerning the expenditure mix. However, it does not have to include detailed rules on what amount of which public good to provide. It is sufficient to require that in situations where no audit takes place the agency provide at least $g_N^{L*}(q)$ of each public good. This is in accord with the interest of the agency head who because of his preferences will provide this amount of the public good for which a low valuation has been realised and the remainder will be provided as the public good for which the high valuation has been realised. In case an audit is performed, the government can again give discretion to the agency to provide the different public goods, provided that at least g_A^{L*} is allocated to each of them. Under this regulation, the agency head will again select the pareto-optimal expenditure mix of (g_1,g_2) given the realised preference intensities (θ_1,θ_2).

This mechanism is equivalent to the true revealing mechanism, because the request for additional funds has the same informational content as the sending of a message about the true state of the world. If the head requests $G_{HH}=2g_{A*}^{HH}$ he sends the message that the true state of the world is (HH) whereas a request for $G_{LH}=G_{HL}=g_A^{L*}+g_A^{H*}$ transmits the information that either of the intermediate states of the world has been realised. Finally, not requesting any additional allocation of public goods (and the funds to finance them) implies that the agency head tells the government that the true state is the bad state (LL) and that he will not need additional allocations beyond the initial allocation $G_{LL}=2g_{A*}^{LL}$. (Although given his preferences and the state of the world he naturally would like to request them but is deterred from doing so by the probability of being subjected to an audit with the respective probabilities $\gamma(LH)=\gamma(HL)$ and $\gamma(HH)$).

Hence commonly observed budgetary rules and regulations in the public sector can be related to the observed structure of a theoretical mechanism which is based on the presumption that executive public officials who are concerned with the collection of relevant information from the private sector have to be prevented from taking individual advantage of the asymmetrically distributed information between themselves and the political entities governing their activities.

4. Summary of results

It has been the purpose of this paper to illustrate parallels between active research issues in the theory of corporate finance and in the economic organisation of government activities.

The mechanism developed in the previous section which is based on the structure developed by Harris/Raviv (1998) has been shown to work not only on the sphere analysis for which those authors developed it, namely budgeting in the area of investment. It also is applicable for areas in the public sector where public officials in bureaucratic agencies are tasked with the acquisition of information relevant for policy making in the sense of providing different public goods for a representative household who may have different preference intensities.

Budgetary rules can be used to elicit information from well-informed government agents who are inclined to use their informational advantage to their own benefit. In contrast to many standard applications in this area this private benefit is not a quasi-profit they receive from consumption on the job or illicit private consumption, but their utility increases if the available amount of public goods/ the size of public facilities/their budget is increased. The conflict of interest between the agency decision maker and policy makers who perfectly represent the interests of the representative citizen arise from the fact, that the agency decision maker cares only about public goods and not about private welfare per se. However, as far as the optimal mix of public goods is concerned, there is no conflict of interest between the agency and the general public. This approach might in the future offer a middle road between the extreme perspectives of the benevolent public servants favoured by Musgrave (e.g. see his contributions in Buchanan/Musgrave (1998)) and the egotistic selfish Leviathan of Buchanan (e.g. see his contributions in Buchanan/Musgrave (1998)), who must be constrained by rules, laws and constitutions. It offers a perspective on public servants more in alignment with principal-agent theory in that it treats public sector agents as agents with interests of their own who are not fundamentally opposed to the public interest as Leviathan is.

References

Becker, G.S., Stigler, G.J. 1974. Law enforcement, malfeasance, and compensation of enforcers. Journal of Legal Studies 3, 1-18.

Besley, T.J., Jewitt, I. 1991. Decentralisation and public good supply. Econometrica. 59, 1769-1887.

Boadway, R., Horiba, I., Jha, R. 1999, The provision of public services by government funded decentralized agencies, Public Choice 100, 157-184.

Boadway, R., Marceau, N., Sato, M. 1999. Agency and the design of welfare systems. Journal of Public Economics 73, 1-30.

Bös, D. 1991. Privatization: a theoretical treatment. Oxford.

Bös, D. 2000. Privatization under asymmetric Information. Cesifo Working Paper No. 244. Munich.

Buchanan, J.M., Musgrave, R.A. 1998. Public finance and public choice: two contrasting visions of the state. Cambridge, MA.

Cremer, H., Gahvari, F. 2000. Tax evasion, fiscal competition and economic integration. European Economic Review 44, 1633-1657.

Cremer, H., Marchand, M., Pestieau, P. 1996. International redistribution through tax surcharge. International Tax and Public Finance 3, 157-73.

Dewatripont, M., Jewitt, I., Tirole, J. 1999. The economics of career concerns, Part 2: Application to missions and accountability of government agencies. Review of Economic Studies 66, 199-217.

Dhillon, A., Perroni, C., Scharf, K. 1999. Implementing tax coordination, Journal of Public Economics 72, 243-268.

Gordon, R.H., Wilson, J.D. 1999. Tax structure and government behavior: Implications for tax policy. NBER Working paper 7244. Cambridge, MA. National Bureau of Economic Research.

Gordon, R.H., Wilson, J.D. 2003. Expenditure competition. Journal of Public Economic Theory 5, 399-417.

Groves, T., Ledyard, J. 1977. Optimal allocation of public goods: a solution to the "freerider" problem. Econometrica 45, 783-809

Harris, M., Raviv, A. 1996. The capital budgeting process: Incentives and information. Journal of Finance, 51, 1139-1174.

Harris, M., Raviv, A. 1998. Capital budgeting and delegation. Journal of Financial Economics 50, 259-289.

Laffont, J.-J. 2000, Incentives and Political Economy, Oxford University Press, Oxford.

Mueller, D.C. 2003. Public Choice III. Cambridge University Press. Cambridge.

Nielsen, S.B. 1998. On optimal capital income tax policies. European Economic Review 42, 1553-1580.

Niskanen, W.A. Jr. 1971. Bureaucracy and Representative Government, Aldine, Chicago.

Tirole, J. 1994. The internal organization of government. Oxford Economic Papers, 46. 1-29.

Williamson, O.E. 1967. The economics of discretionary behaviour: Managerial objectives in a theory of the firm. Chicago University Press, Chicago

Williamson, O.E. 1999. Public and private bureaucracies: A transaction cost perspective. Journal of Law, Economics and Organization 15 306-342.

Wilson, J.D. 2000. Welfare-Improving Competition for Mobile Capital. Mimeo. Department of Economics, Michigan State University.

Table 1

q	$\gamma(LH)$	$\gamma(HH)$	G_{HH}	G_{LL}	G_{LH}
0	0.115012	0.206299	2.51984	2	2.25992
0.1	0.098862	0.192729	2.51283	2.02854	2.25109
0.2	0.082530	0.179041	2.5058	2.05716	2.24221
0.3	0.066015	0.165234	2.49876	2.08588	2.23331
0.4	0.049333	0.151325	2.49169	2.11463	2.22437
0.5	0.032458	0.137292	2.4846	2.14349	2.21539
0.6	0.015411	0.123153	2.47749	2.17238	2.20639
0.6895	0	0.110408	2.47112	2.19828	2.19828
0.7	0	0.108908	2.47037	2.20132	2.20132
0.8	0	0.094556	2.46322	2.23031	2.23031
0.9	0	0.080101	2.45605	2.25932	2.25932
1	0	0.065543	2.44887	2.28836	2.28836
1.1	0	0.050883	2.44166	2.31742	2.31742
1.2	0	0.036124	2.43443	2.34649	2.34649
1.3	0	0.021265	2.42719	2.37557	2.37557
1.4	0	0.006307	2.41992	2.40466	2.40466
1.442	0	0	2.41686	2.41686	2.41686
1.5	0	0			

Figure 1

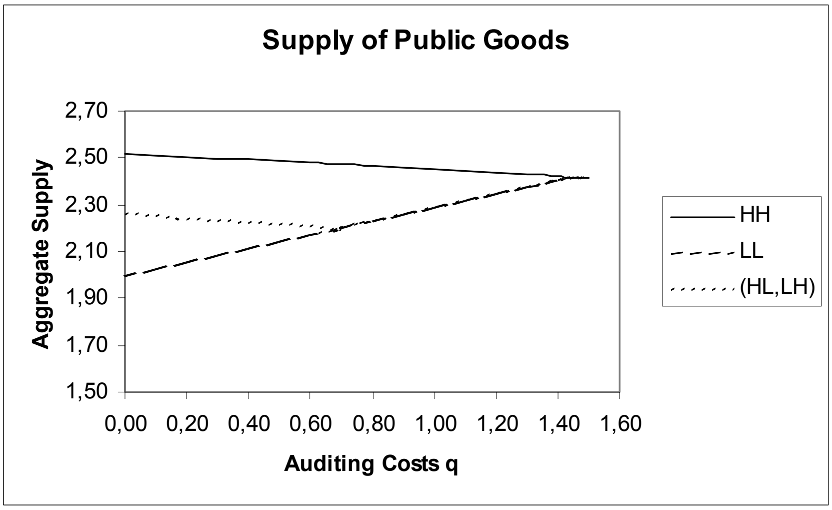
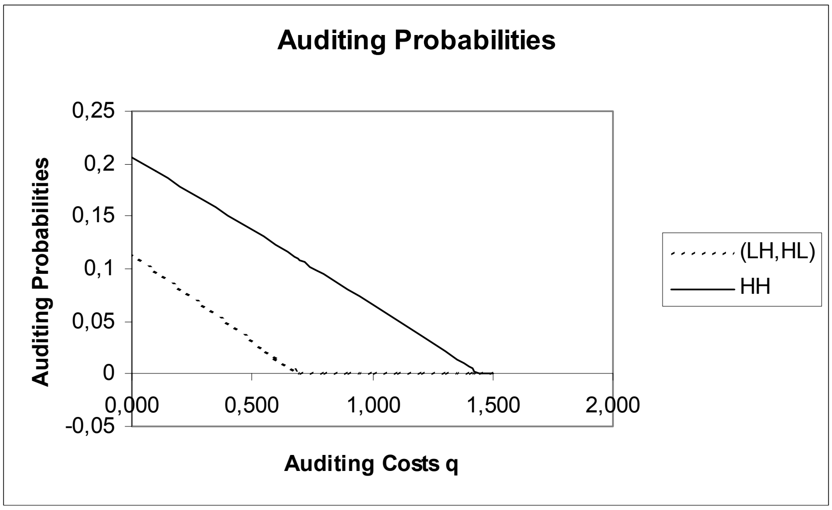


Figure 2



Würzburg Economic Papers

99-01	Peter Bofinger	The monetary policy of the ECB: pretence and reality
99-02	Adalbert Winkler	Promotional banks as an instrument for improving the financing situation of small and medium sized enterprises in the transition economies of Central and Eastern Europe
99-03	Werner Ebert and Steffen Meyer	Die Berücksichtigung der Gemeindefinanzen im Länderfinanzausgleich
99-04	Horst Entorf	Der deutsche Aktienmarkt, der Dollar und der Aussenhandel
99-05	Norbert Schulz	A comment on Yin, Xiangkan and Yew-kwang Ng: quantity precomment and Bertrand competition
99-06	Norbert Schulz	Third-degree price discrimination in an oligopolistic market
99-07	Norbert Schulz	Capacity constrained price competition and entry deterrence in heterogeneous product markets
99-08	Hans Fehr	Pension reform during the demographic transition
99-09	Hans G. Monissen	Explorations of the Laffer curve
99-10	Hans G. Monissen	Knut Wicksell und die moderne Makroökonomik
99-11	Hans E. Loef and Hans G. Monissen	Monetary Policy and monetary reform: Irving Fisher's contributions to monetary macroeconomics
99-12	Hans G. Monissen	Reflections on the optimal size of government
00-13	Peter Bofinger and Timo Wollmershäuser	Options for the exchange rate policies in the EU accession countries (and other emerging market economies)
00-14	Peter Bofinger and Timo Wollmershäuser	Monetary Policy and Exchange Rate Targeting in Open Economies
00-15	Nicolas Schlotthauer	Currency and financial crises – lessons from the Asian crises for China?
00-16	Timo Wollmershäuser	ESZB-Devisenbestand - quo vadis?
00-17	Norbert Schulz	Thoughts on the nature of vetoes when bargaining on public projects
00-18	Peter Bofinger	Inflation targeting - much ado about nothing (new)
00-19	Horst Entorf and Gösta Jamin	"German stock returns: the dance with the dollar"
00-20	Horst Entorf	Erscheinungsformen und Erklärung von Mismatch am Arbeitsmarkt: Ansatzpunkte für eine zielgerichtete Arbeitsmarktpolitik
00-21	Francesco Parisi, Norbert Schulz and Ben Depoorter	Duality in Property: Commons and Anticommons
00-22	Horst Entorf	Criminality, social cohesion and economic performance
00-23	Horst Entorf	Rational migration policy should tolerate non-zero illegal migration flows
00-24	Hans Fehr, Wenche Irén Sterkeby and Oystein Thogersen	Social security reforms and early retirements
00-25	Norbert Schulz	Private and social incentives to discriminate in oligopoly
00-26	Horst Entorf	James Heckman and Daniel McFadden: Nobelpreis für

		die Wegbereiter der Mikroökonometrie
01-27	Norbert Schulz	Profitable Cannibalization
01-28	Adalbert Winkler	On the need for an international lender of last resort: Lessons from domestic financial markets
01-29	Horst Entorf and Peter Winker	The Economics of Crime: Investigating the Drugs-Crime Channel - Empirical Evidence from Panel Data of the German States
01-30	Peter Bofinger and Timo Wollmershäuser	Managed floating: Understanding the new international monetary order
01-31	Norbert Schulz, Francesco Parisi and Ben Depoorter	Fragmentation in Property: Towards a General Model
01-32	Stephan Fasshauer	Das Principal-Agent-Verhältnis zwischen Bevölkerung und Politik als zentrales Problem der Alterssicherung in Deutschland
02-33	Peter Bofinger	The EMU after three years: Lessons and challenges
02-34	Peter Bofinger, Eric Mayer, Timo Woll-mershäuser	The BMW model: a new framework for teaching monetary macroeconomics in closed and open economies
02-35	Peter Bofinger, Eric Mayer, Timo Wollmershäuser	The BMW model: simple macroeconomics for closed and open economies – a requiem for the IS/LM-AS/AD and the Mundell-Fleming model
03-36	Robert Schmidt	Zur Qualität professioneller Wechselkursprognosen – Sind professionelle Wechselkursprognosen eine sinnvolle Entscheidungshilfe für Unternehmen und Investoren?
03-37	Patrick F.E. Beschorner	Risk Classification and Cream Skinning on the Deregulated German Insurance Market
03-38	Peter Bofinger and Robert Schmidt	**Should one rely on professional exchange rate forecasts? An empirical analysis of professional forecasts for the €/US-$ rate**
03-39	Schmidt and Peter Bofinger	**Biases of professional exchange rate forecasts: psychological explanations and an experimentally based comparison to novices**
03-40	Peter Bofinger and Eric Mayer	**Monetary and fiscal policy interaction in the Euro Area with different assumptions on the Phillips curve**
03-41	Eric Mayer	**The mechanics of a reasonably fitted quarterly New Keynesian macro model**
03-42	Peter Bofinger, Eric Mayer and Timo Wollmershäuser	**The BMW model as a static approximation of a forward-looking New Keynesian macroeconomic model**
03-43	Oliver Hülsewig	**Bank Behavior, Interest Rate and Monetary Policy Transmission**
03-44	Kathrin Berensmann	**Monetary Policy under Currency Board Arrangements: A Necessary Flexibility of Transition**
03-45	Hans Fehr, Gitte Halder, Sabine Jokisch and Larry Kotlikoff	**A Simulation model for the demographic transition in the OECD – Data Requirements, model structure and calibration**

03-46	Franscesco Parisi, Norbert Schulz and Ben Depoorter	**Symmetry and asymmetrs in property: commons and anticommons**
04-47	Hans Fehr and Christian Habermann	**Pension Reform and Demographic Uncertainty: The Case of Germany**
04-48	Hans Fehr, Gitte Halder and Sabine Jokisch	**A Simulation Model for the Demographic Transition in Germany: Data Requirements, Model Structure and Calibration**
04-49	Johannes Leitner and Robert Schmidt	**A systematic comparison of professional exchange rate forecasts with judgmental forecasts of novices**
04-50	Robert Schmidt and Timo Wollmershäuser	Sterilized Foreign Exchange Market Interventions in a **Chartist-Fundamentalist Exchange Rate Model**

Download: http://www.wifak.uni-wuerzburg.de/vwl1/wephome.htm