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The Impact of Spatial Spillovers in a Decentralised Target-Driven Policy Regime *

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ABSTRACT

The present UK government has introduced a decentralised, target-driven framework for the delivery of regional policy in England. This paper analyses the operation of such a regime when there are spatial spillovers about which the government is uninformed. It stresses the simple idea that spillovers in such a setting normally lead to a sub-optimal allocation of policy expenditures. A key result is that the existence of negative spillovers on some policies generates expenditure switching towards those policies. The extent of the expenditure switching is related to a number of factors: the size of the spillovers; the initial policy weights in the government's welfare function; the number of agencies; the extent of their knowledge of spillovers; and their degree of collusion. Such expenditure switching is generally not welfare maximising.

Keywords: Targets, Regional Policy, Regional Development Agencies, Spatial Spillovers.

JEL Classification: R38

1. INTRODUCTION

The present UK government has begun a radical overhaul of regional policy, as outlined in HM Treasury (2001) and HM Treasury *et al* (2003). Two changes are of particular importance to this paper. First, regional policy is no longer directed solely to poorly performing regions: rather it aims to help each region to maximise its economic potential. Second, the delivery of regional policy in England has been decentralised and delegated to Regional Development Agencies, RDAs, which are motivated and controlled through fixed budgets and target setting. This is an explicit attempt to extend the principle of "constrained discretion" which has been adopted with such apparent success in the operation of monetary policy (McVittie and Swales, 2004a). A major premise underpinning this decentralisation is that indigenous regional institutions have informational advantages over central government. These local organisations are thought to be able to deliver a more flexible and discretionary regional policy that is sensitive to local economic conditions (HM Treasury *et al.,* 2003).[i]

Our specific concern is the operation of such a target-driven regime where there are policy spillovers across regions. We analyse this problem in a principal-agent framework with asymmetric information concerning the size of the policy spillovers. The government (the principal) is generally uninformed and the regional agencies (the agents) either informed or uninformed. Further, informed development agencies can either act non-cooperatively or collusively in attempting to meet the policy targets. We demonstrate that in this setting there is expenditure switching towards the policy with the negative spillovers. In general, the degree of switching will be positively related to: the size of the spillovers; the initial weight of the policies with spillovers in the government's welfare function; the lack of knowledge by the agencies; the number of agencies; and their lack of collusion. In welfare terms, such expenditure switching is likely to be sub-optimal and in numerical simulations we identify the possible size of these welfare losses.

We believe this problem is of practical significance for the operation of English regional policy. The English regions are extremely open in terms of trade and factor mobility, so that spillover effects are to be expected (Krugman, 2005). However, there is no consensus as to the size, or even the sign, of such effects. This is partly because past work on identifying regional policy impacts has focused almost exclusively on the recipient region. This primarily reflects two factors: the concern of previous regional policy with "problem" regions, and the difficulty in isolating the spatially diffuse spillover effects. The impact of regional policy on non-recipient regions or the nation as a whole is therefore under-researched (Taylor, 2002). Further, the UK data on some of the channels through which such spillovers might act - in particular inter-regional trade and migration - are at present extremely limited (Alsopp, 2003, McVittie and Swales, 2004b). In so far as the problems identified in this paper are eliminated if the government is informed as to the nature of spatial policy spillovers, the paper is making a *prima facie* case for better information and more empirical research on these effects.

The paper proceeds as follows. Section 2 gives more background information on the recent changes in UK regional policy. Section 3 outlines a formal model with no spillovers. Section 4 introduces policy spillovers and Section 5 details the target-driven regime. Sections 6 and 7 give model solutions with uninformed and informed development agencies respectively. Section 8 discusses positive spillovers. Section 9 investigates the implications for welfare of the expenditure switching produced in the model, with Section 10 reporting numerical simulation results. Section 11 is a short conclusion.

2. RECENT CHANGES IN UK REGIONAL POLICY

The post-1997 Labour government introduced an innovative regional policy framework, referred to as the 'new localism', which involves the devolution or delegation of power and responsibility over regional policy to decentralised bodies (Balls, 2002). The distinction between devolution and delegation is important. In Scotland, Wales and Northern Ireland policy concerning economic development has been devolved to the appropriate parliament or assembly which have a wide degree of freedom over their own development priorities, policy design and the associated allocation of resources (HM

Treasury *et al*, 2003)[ii]. On the other hand, in England regional policy has been decentralised and delegated and operates in the following way.

Central government allocates to London and the eight English regions funds that are specifically earmarked for regional economic development. This is a change, in that policy now covers all the regions, not simply specifically identified “problem” areas. The expenditure of these regional funds is subject to incentives and constraints set at the national level. The relevant regional institutions in England therefore determine the manner in which regional policy is to be delivered. However, they do not control the overall aims or aggregate level of regional assistance.

The bodies that lead in the local delivery of this policy are the newly formed English Regional Development Agencies, RDAs, which are non-departmental public bodies, NDPBs. An NDPB is a “body which has a role in the process of national government, but is not a government department or part of one, and accordingly operates to a greater or lesser extent at arms length from Ministers” (RDAUK Homepage, 2001). This gives the RDAs a degree of independence and flexibility when dealing with the private sector which government departments might lack. The government argues that delegating responsibility over regional policy allows the RDAs to use their region-specific knowledge in order to exploit the indigenous strengths, and tackle the particular weaknesses, of each area (HM Treasury *et al*, 2003). The English RDAs are allocated a significant budget, which is forecast to be over £2 billion by 2005-6 (McVittie and Swales, 2004b).

Although the RDAs have been given discretion over their use of resources, they are set targets for economic development and regeneration.[iii] These targets are linked to the Public Service Agreement, PSA, targets held by the Departments that fund the activities of the English RDAs (HM Treasury, 2004; HM Treasury *et al*, 2003). It is well known that using targets to control delegated agents has weaknesses as well as strengths (Milgrom and Roberts, 1992). In this paper we specifically investigate the effectiveness of a regional target-driven regime where there are significant interregional policy spillovers; that is, where policy introduced in one region positively or negatively affects the economic performance of other regions. Examples of the channels through which such economic spillovers might flow include product and labour markets, migration, and informational networks (Ferguson *et al*, 2004; Fingleton, 2003; Krugman, 2005).

3. A FORMAL DELEGATED-POLICY MODEL WITH NO SPILLOVERS

The broad characteristics of the model are as follows. A finance-constrained government department (subsequently referred to as 'the government') has a social welfare function whose arguments are measures of regional utility. For individual regions, utility is a function of two regional policy outputs and the government delegates policy delivery to decentralised economic development agencies. Each agency is allocated a budget, and known linear technologies transform efficient expenditure to policy outputs, but one of the policy outputs generates spatial spillovers. There are conventional moral hazard problems for the government; it cannot observe agency effort or misdirected expenditure, only policy outputs. It therefore sets targets for the policy outputs of the individual agencies, and there is an associated loss function that operates if an agency fails to hit the targets.

Essentially we adopt a principal-agent approach, with the government as the principal and the development agency as the agent (Laffont and Martimort, 2002). We therefore consider the government's attempts to set targets which optimise the government's pay-off, which is expressed as a welfare function. Though we do not treat the agencies' participation constraints in a fully rigorous manner, we do assume that amongst the targets that maximise its pay-off, the government chooses the set that minimises the cost to the agencies. This is consistent with the present UK government's rule that targets should be SMART, where SMART is an acronym for *S*pecific, *M*easurable, *A*chievable, *R*elevant and *T*imed (HM Treasury, 2003). Targets that are achieved will register a zero (minimum) score on the agencies' loss functions.

More specifically, the model has n identical regions. The government has a symmetrical concave welfare function, W, in the regions' utilities where U_i is the utility in region i, so that:

(1) $$W = W(U_1, U_2, ..., U_n)$$

where:

$$\frac{\partial W}{\partial U_i} \geq 0, \quad \frac{\partial^2 W}{\partial U_i^2} \leq 0 \qquad \forall_i$$

The regional utility function does not vary across regions and is taken to be a linear homogenous function of the two policy outputs[iv]:

(2) $$U_i = U(Q_{1,i}, Q_{2,i}) \qquad \forall_i$$

where $Q_{k,i}$ is the output of policy k in region i, and

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$$\frac{\partial U_i}{\partial Q_{k,j}} \geq 0, \quad \frac{\partial^2 U_i}{\partial Q_{k,j}^2} \leq 0 \qquad \forall_{i,j,k}$$

Finally, there is a linear relationship between efficient policy expenditure and the corresponding policy output that does not vary across regions. The symmetry of the spatial set up here suggests more a decentralised industrial policy than conventional regional policy. However, this is exactly how the recent innovations in UK regional policy are characterised by some authors (Wren, 2001).

We begin by considering a situation where there are no policy spillovers. This implies that the regional policy outputs are determined as:

(3) $$Q_{k,i} \leq \gamma_k P_{k,i} \qquad \forall_{k,i}$$

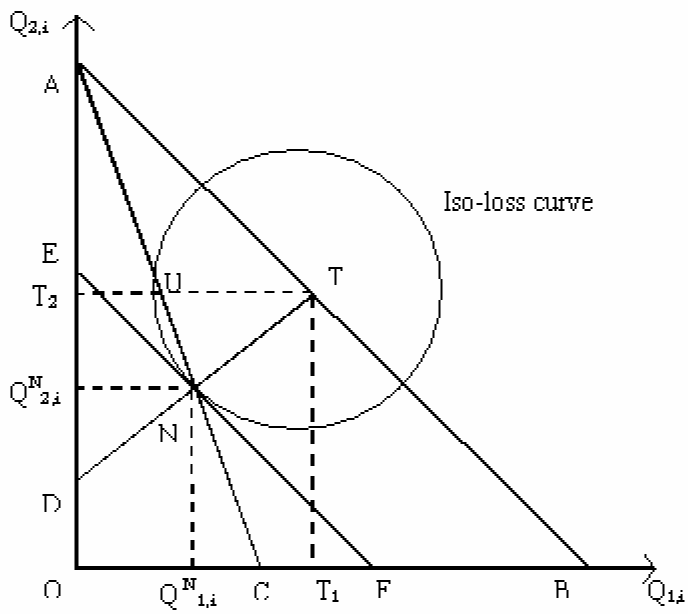
where $P_{k,i}$ is the expenditure on policy k in region i, and γ_k is a fixed technical coefficient determining the efficient transformation of expenditure into output for policy k. For expression (3) to hold as an equality, two important conditions must hold. First, the policy must be delivered locally. If it is delivered outwith the region, the effectiveness of policy expenditure is much reduced. Second, the policy must be pursued with maximum effort. As long as these two conditions hold, we assume policy can be delivered at a uniform efficiency across regions.

For heuristic reasons, we parameterise equation (3) such that the transformation parameters, γ, and the total budget take the value unity. To deliver the optimal policy outcome, the total budget should be split evenly between all regions, so that each receives a budget of $\frac{1}{n}$. The optimal regional outputs of policies 1 and 2 ($Q^*_{1,i}$, $Q^*_{2,i}$) and the corresponding regional targets ($T_{1,i}$, $T_{2,i}$) can then be expressed as:

(4) $$Q^*_{1,i} = T_{1,i} = \frac{\alpha}{n}, \quad Q^*_{2,i} = T_{2,i} = \frac{1-\alpha}{n} \qquad \forall_i$$

where α is a policy weight derived from the welfare function implied by equation (2), $1 > \alpha > 0$. The zero-spillovers case is represented graphically by the negatively sloped 45° budget constraint line AB in Figure 1. The target point, T, and optimal outputs, $\frac{\alpha}{n}, \frac{1-\alpha}{n}$, are also shown. An important detail here is that the individual targets are (just) jointly attainable and equal to the optimal policy outputs. As an example, the optimal targets and outputs where the utility function in equation (2) is Cobb-Douglas are derived formally in Appendix 1.

Figure 1: The equilibria for uninformed target-driven agencies



Before continuing, it is helpful to clarify our approach. The assumptions made in this section focus the analysis purely on the problems of delegation and target-driven behaviour associated with the policy of "constrained discretion" accompanied by spillovers. Two issues should be made clear. These concern the homogeneity of regions and the dependence of direct policy efficiency on the degree of policy decentralisation.

The utility functions given in equation (2) imply that regions are homogeneous. Of course, one of the key reasons for decentralised policy delivery is that regions differ. We do not confront this problem here. More importantly, in subsequent analysis where we vary the number of administrative regions, we assume that the scale of the representative region changes, but each is still identical. Therefore comparing the government's welfare under regimes with n or m regions, and assuming in both cases identical utility across regions:

(5) $$W^m\left(\frac{n\bar{U}_i^n}{m}\right) = W^n(\bar{U}_i^n)$$

where the superscripts indicate the number of regions and the bar the fact that all the regions' utilities are identical.[v]

Similarly, where we vary the number of regions, we hold the value of the direct policy coefficients, γ_1 and γ_2, constant. Again, one of the key reasons for decentralisation is to improve direct policy delivery. This would suggest a non-linear relationship between the direct policy coefficients and the size of the region, with direct policy effectiveness rising and then falling as the number of regions rose (and their individual sizes fell). We do not introduce this problem formally but do note in Section 9 a potential tension between the optimal scale for direct policy effectiveness and that for internalising negative spillover effects.

4. THE INTRODUCTION OF POLICY SPILLOVERS

We now introduce spillovers associated with expenditure on Policy 1. We assume that the spillover takes the following form: a change in expenditure on Policy 1 in one region has a spillover effect on the output of Policy 1 in the nation as a whole. This effect is evenly spread amongst all regions. On the other hand, the expenditure on Policy 2 generates no spatial spillover effects. The operation of Scottish Enterprise, the regional development agency in Scotland, provides good examples of both types of policy. Ferguson *et al* (2004) report simulations showing negative output and employment effects on the rest of the UK from agency-supported policies to increase Scottish exports. This is an example of Policy 1.[vi] However, there are other policies, such as "Narrowing the gap between unemployed in the worst areas of Scotland and the Scottish average" which invests in human capital in order to reduce unemployment in the most deprived areas of Scotland (Scottish Enterprise, 2002). As such, this policy fulfils a primarily redistributive role and is therefore unlikely to have effects outwith the region. This is an example of Policy 2.

We concentrate initially on negative spillovers. This is for two main reasons. First within the present framework they are theoretically more interesting. Second, negative spillovers are thought to be more prevalent in practice. Ferguson *et al* (2004) identify strong negative spillovers in their preferred UK multi-regional policy simulation results. However, in Section 8 we briefly discuss the impact of positive spillovers.[vii]

Where there are spillover effects we distinguish two separate impacts of regional policy. First, a direct effect that operates exactly as in the zero-spillover case. Second, there is an additional national spillover effect. Therefore for an expenditure on Policy 1 in region i of $P_{1,i}$, there is an accompanying national spillover equal to $\varphi P_{1,i}$ that is distributed evenly amongst all the regions. Given that we are considering negative spillovers at present, we give ϕ a negative sign, so that the outputs of locally-delivered Policies 1 and 2 in region i are given as:

(6) $$Q_{1,i} \le P_{1,i} - \frac{\phi}{n}\sum_{j=1}^{n} P_{1,j}$$

(7) $$Q_{2,i} \le P_{2,i}$$

with each expression holding as an equality only under maximum effort.[viii] It is assumed that $0 < \phi \le 1$. This implies that the negative national spillover effect is not greater than the direct regional impact of Policy 1.

The introduction of the negative spillover operates, at the national level, as a reduction in the efficiency in the production of output of Policy 1. In equilibrium the expenditure on Policy 1 in each region will be identical, so that from equation (6):

(8) $$Q_{1,i} \le (1-\phi)P_{1,i}$$

Therefore in Figure 1, the locus of possible equilibrium policy outputs is given not by the line AB, whose slope is –1, but rather by the line AC, which has the steeper negative slope $-\frac{1}{1-\phi}$. AC is the equilibrium Policy Possibility Frontier (PPF) for policy outputs 1 and 2. Our interest is in analysing the impact of target setting by a government that is uninformed about the spillovers on the output of Policy 1. This means that the government believes the value of ϕ to be zero and therefore sets the target levels at T. However, the regional agencies are unable to attain the targets on these two outputs simultaneously, so become driven by minimising the loss implied by not achieving their targets.

It might seem unusual to characterise the principal (the government) as being systematically mistaken about the constraints that the agents face. However, as we have argued already, there is little knowledge about the national impacts of regional policy (Taylor, 2002). Further, the most recent government publication on UK regional policy stresses that aid is to help each region reach its full economic potential (HM Treasury *et al*, 2003). The notion that there might be possible conflicts between the different regions simultaneously achieving their policy aims is downplayed in this document. So is any conception that regions are inter-related and operate together to make up the national economy with national economic constraints (Ferguson *et al*, 2004; Gillespie *et al*, 2002; McGregor and Swales, 2005). Given this background, it is plausible to believe that in practice targets might be set with little prior regard to possible spatial spillover effects.

5. THE TARGET-DRIVEN REGIME

We begin by outlining how the behaviour of the agencies is affected by the introduction of a target-driven regime. The agencies will be punished for deviating from targets set by the government, where this punishment consists of adverse reputation effects. We use the same form of loss function as popularised in the literature on monetary targets (Barro and Gordon, 1983; Rogoff, 1985):

(9) $$\Lambda_i = (Q_{1,i} - T_{1,i})^2 + (Q_{2,i} - T_{2,i})^2 \qquad \forall_i$$

where Λ_i is the development agency's total loss.[ix] With this function the total and marginal loss increases as the distance from the target increases.

Equation (9) implies a symmetric target: the costs of over- and under-achievement are equal. Such an assumption is clearly appropriate for the targets such as that set for the Monetary Policy Committee, where the UK government requires a predictable, and stable, inflation rate (Balls *et al*, 2002). In a regional policy context, however, it is likely that, from the government's point of view, the targets will be asymmetric. In general, we expect the government to prefer more regional policy output than less, so that it will impose no punishment for exceeding a target.[x] However, we do not explicitly model development agency effort. We therefore identify the loss involved in exceeding the target as being the cost to the agency of excess effort. This means that whenever the agency can meet the target within its budget, the agency will prefer to hit the target with minimum effort, rather than overshoot the target.

The agency therefore chooses policy output levels that minimise its loss function, subject to the appropriate informational and technical constraints. We consider a number of scenarios in which economic actors have alternative information about spillovers. Agencies can be informed or uninformed about spillover effects. If they are uninformed, all the agencies believe the value of ϕ to be zero and interpret any under-performance in producing Q_1 to have some unobserved exogenous cause. If the agencies are informed, the true value of the spillover, ϕ, is common knowledge to all agencies. However, at this point we assume the government to be uninformed about policy spillovers, therefore believing the value of ϕ to be zero. The government interprets low attainment of Policy 1 to be the result of low or misdirected effort.

6. MODEL SOLUTIONS WITH UNINFORMED AGENCIES

We begin by simply considering how the regional agencies react to being set targets that are unattainable due to the existence of negative spillovers. We focus on the extent of expenditure shifting between policy outputs 1 and 2, without commenting on whether or not such expenditure shifting is optimal. This present section investigates the actions of uninformed agencies, whilst Section 7 concentrates on informed agencies.

Proposition 1: Over time, uninformed agencies will switch expenditure towards the policy activity that has the negative spillover.

In the one-shot uninformed solution, each regional agency chooses the expenditure level that minimises the expected value of its loss function, on the misguided assumption that there are no spillovers. The expected policy outputs are therefore given by equation (3), where the values of γ_1 and γ_2 are normalised to unity. In order to hit the targets $\frac{\alpha}{n}, \frac{1-\alpha}{n}$ each agency will therefore commit corresponding expenditure levels. However, due to the negative spillover for Policy 1, the actual outcomes will be $\frac{(1-\phi)\alpha}{n}, \frac{1-\alpha}{n}$. The spillover from expenditure on Policy 1 by the agencies in the other regions pushes the performance of each agency further away from T_1 than expected and increases its "loss". Instead of being at point T in Figure 1, each agency will be at point U. Instead of being on the expected policy constraint line AB, they are actually on AC. The *ex post* payoff to each agency will be $-\left[\frac{\phi}{n}\right]^2$.

Given their expectations, the strategy adopted by the agencies was *ex-ante* optimal. Clearly in a repeated game situation we expect the agencies to reallocate funds between the different policies. As outlined in Section 5, the uninformed agencies interpret any failure to meet the target for Policy 1 as the result of some unobserved exogenous disturbance. In a repeated game with fixed targets and backward looking adjustments, Appendix 2 details how agency expenditures over time can be represented as the difference equations:

(10) $$P_{1,i,t} = \frac{\alpha}{n} + \frac{\phi P_{1,i,t-1}}{2}, \quad P_{2,i,t} = \frac{1-\alpha}{n} - \frac{\phi P_{1,i,t-1}}{2} \qquad \forall i$$

This is represented in Figure 2, where the dashed line shows the adjustment path over time. Substituting the equilibrium condition $P_{1,i,t} = P_{1,i,t-1}$ into equation (10) produces:

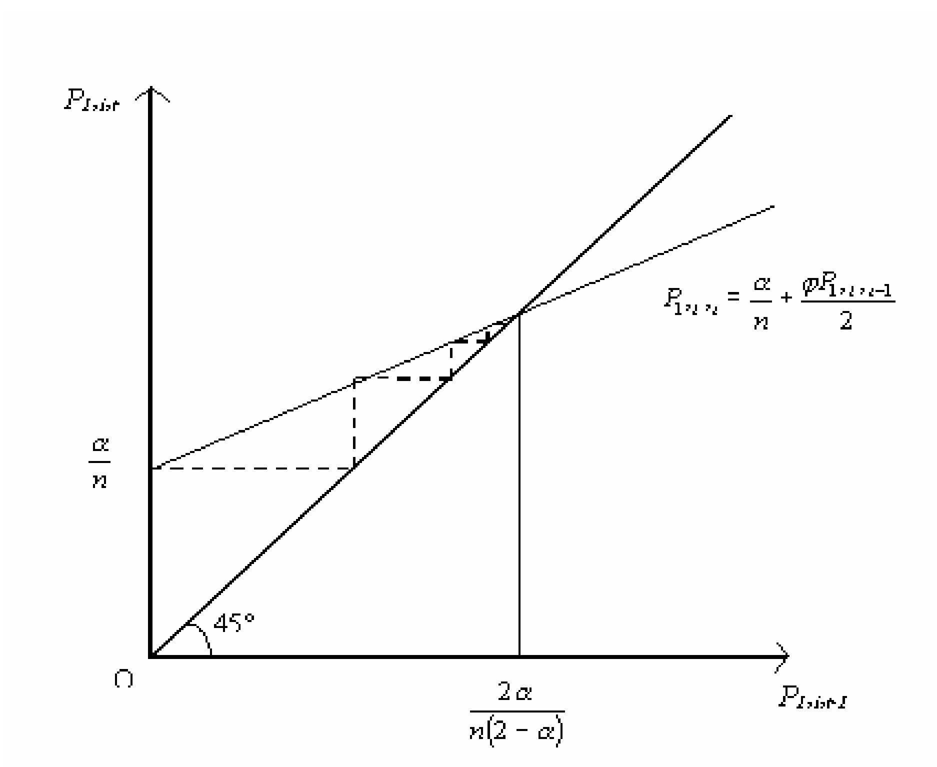
$$P_{1,i}^{e} = \frac{2\alpha}{n(2-\phi)}, \quad P_{2,i}^{e} = \frac{2(1-\alpha)-\phi}{n(2-\phi)} \qquad \forall_i \tag{11}$$

where the e superscript indicates equilibrium values. If we represent the change between the expenditures with and without spillovers by the term Δ, then:

$$\Delta P_{1,i} = -\Delta P_{2,i} = \frac{\alpha\phi}{n(2-\phi)} \qquad \forall_i \tag{12}$$

Therefore in the target-setting framework identified here, over time uninformed agencies shift expenditure towards the policy with the negative spillover.

Figure 2: Difference equation for uninformed target-driven agency



Proposition 2: For uninformed agencies, the extent of the switching within the national programme is unrelated to the number of agencies.

Proposition 3: Expenditure switching will be greater, the greater the negative spillover and the bigger this policy's weight in the government's welfare function.

Propositions 2 and 3 follow directly from expression (12). For Proposition 2, the extent of expenditure shifting within the programme as a whole (ΔP_1) can be found by multiplying the regional figure ($\Delta P_{1,i}$) by the number of regions, n, which gives:

(13) $$\Delta P_1 = -\Delta P_2 = \frac{\alpha\phi}{2-\phi}$$

The implication of this result is that even if the operation of regional policy were delegated to only one uninformed agency, the expenditure switching would be just the same as if the policy had been delegated to numerous similarly uninformed, geographically distinct agencies.

For Proposition 3, partially differentiating expression (13) with respect to α and ϕ gives the results.

$$\frac{\partial \Delta P_1}{\partial \alpha} = -\frac{\partial \Delta P_2}{\partial \alpha} = \frac{\phi}{(2-\phi)} > 0$$

$$\frac{\partial \Delta P_1}{\partial \phi} = -\frac{\partial \Delta P_2}{\partial \phi} = \frac{2\alpha}{(2-\phi)^2} > 0$$

The size of the expenditure shift is therefore positively related to both α and ϕ. However, a more intuitive demonstration of these results can be given using Figure 1. With negative spillovers to Policy 1, in equilibrium each agency must lie on the line AC. But uninformed agencies (wrongly) believe that there is a one-for-one trade off between outputs of Policies 1 and 2; that is, they believe themselves to be on a policy production frontier which is parallel to AB with a slope of –1. In equilibrium, this believed Policy Production Frontier must be tangent to the iso-loss function closest to T. The locus of such points is a positively sloped 45° line, TD, ending at T. The uninformed equilibrium is therefore at point N in Figure 1, where lines AC and DT intersect. Over time, the iterative adjustment takes the agency from point U to point N, with a steady switching of expenditure towards Policy 1.[xi] At N, the agency believes itself to be on the policy production frontier EF.

At the iterated equilibrium, the policy outputs are $Q^N_{1,i}$, $Q^N_{2,i}$. Ruling out corner solutions, from inspection, the steeper the line AC, the lower the value of $Q^N_{2,i}$, which also equals the new value of the expenditure on Policy 2. Of course if less is spent on Policy 2, expenditure is switching towards Policy 1. Similarly, *ceteris paribus*, the further down the line AB is located the target point T - that is, the higher the value of the weight, α, on Policy 1 - the larger the negative adjustment in the value of $Q^N_{2,i}$.

7. MODEL SOLUTIONS WITH INFORMED AGENCIES

We now consider the case where regional agencies are informed about the nature of policy spillovers before they choose their expenditure levels in a one shot game.

Proposition 4: The extent of expenditure switching is lower for informed agencies than uniformed agencies. However, as the number of informed agencies increases, the extent of expenditure switching approaches that for uninformed agencies.

Proposition 5: Where the number of agencies is greater than one, as negative spillovers increase, so does the degree of expenditure switching.

If the regional agencies are informed, they know the nature and extent of the negative spillovers and take this into account when making their loss minimising decisions. This means that each agency is aware that its success in reaching the target for the output of Policy 1 will depend upon the expenditure of all the other agencies on that policy. Therefore each regional agency has to make a consistent conjecture about the expenditures in other agencies. We solve by finding the Nash equilibrium.

We begin by deriving the reaction function for the expenditure on Policy 1 by development agency i. Using equations (6) and (9), the Lagrangean is given as:

$$(14) \qquad M\text{ax}\, L_{P_{1,i},P_{2,i},\lambda} = -\left(P_{1,i} - \frac{\phi}{n}\sum_{j=1}^{n} P_{1,j} - T_{1,i}\right)^2 - (P_{2,i} - T_{2,i})^2 + \lambda\left(\frac{1}{n} - P_{1,i} - P_{2,i}\right)$$

Solving for the constrained loss minimising expenditure generates the following reaction function:

$$(15) \qquad P_{1,i} = \frac{n + n(n-\phi)T_{1,i} - n^2 T_{2,i}}{(n-\phi)^2 + n^2} + \frac{(n-\phi)\phi\sum_{j\neq i} P_{1,j}}{(n-\phi)^2 + n^2}$$

If all the expressions for the regional agencies' expenditures on Policy 1 are summed, and the appropriate target values, $\frac{\alpha}{n}, \frac{1-\alpha}{n}$, are substituted for $T_{1,i}$ and $T_{2,i}$, this produces:

$$(16) \qquad P_1 = \frac{(2n-\phi)\alpha}{n(2-\phi) + \phi^2 - \phi}$$

Equation (16) gives the Nash equilibrium value for the national expenditure on Policy 1. Given identical regions, the corresponding regional expenditures equal $\frac{P_1}{n}$.[xii]

We wish to determine for informed agencies how the share of expenditure going to Policy 1 varies as the number of development agencies, n, and the negative spillovers, ϕ, increase. We begin by partially differentiating expression (16) with respect to these two variables.

(17) $$\frac{\partial P_1}{\partial n} = \frac{\phi(2(n-1)\alpha + \phi\alpha)}{(n(2-\phi)+\phi^2-\phi)^2} \geq 0$$

(18) $$\frac{\partial P_1}{\partial \phi} = \frac{\alpha(2n^2 - \phi(4n-\phi))}{(n(2-\phi)+\phi^2-\phi)^2}$$

We check first for the zero spillover case. Substituting $\phi = 0$ into equation (16) gives the expected result: Policy 1 expenditure equals α. Similarly, for $\phi = 0$, from expression (17), the expenditure on Policy 1 does not vary with the number of agencies. However, where there are negative spillovers, so that $\phi > 0$, expenditure shifts to Policy 1; and this shift is larger, the greater the number of agencies.

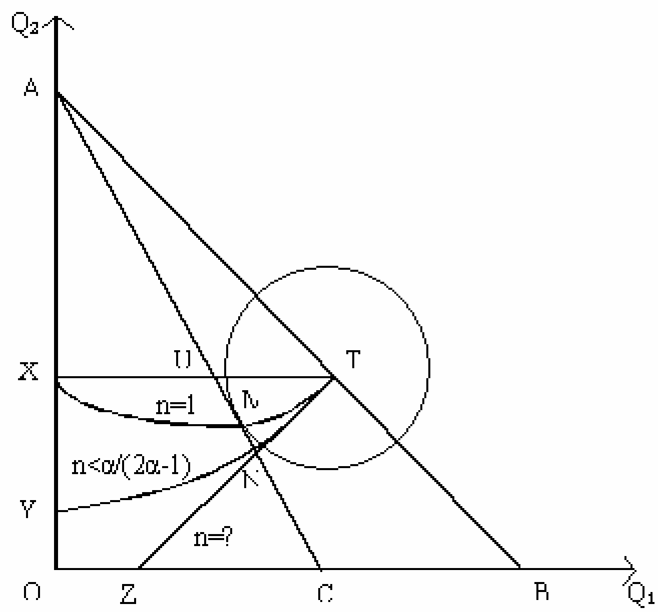
If there is only one informed agency, the agency internalises all the negative spillovers but still faces unattainable targets. In this case, there is expenditure shifting towards the sector with the spillovers. This initial expenditure shift, $\Delta P^M{}_1$, is found by substituting n = 1 into equation (16) and subtracting α. The relevant expression is given as[xiii]:

(19) $$\Delta P_1^M = \frac{\alpha\phi(1-\phi)}{\phi^2 - 2\phi + 2} \geq 0$$

Further, expression (17) shows that with a greater number of informed agencies, the expenditure shifting increases monotonically. This is because the smaller the agency, the bigger the share of the negative spillovers produced by its own policy expenditure that is borne by other agencies. In the limit, as n gets very large, the expenditure shifting approaches that for uninformed agencies. That is to say, as $n \to \infty, P_1 \to \frac{2\alpha}{2-\phi}$. This is the expected result, given that uninformed agencies take no account the operation of the negative spillovers. Therefore the extent of expenditure switching is lower for informed agencies but rises towards the uninformed level as the number of agencies increase.

As the negative spillovers rise, in general the expenditure shifting rises also, though there is one key exception. Consider expression (18). The denominator is always positive, so that the sign of the partial derivative is determined by the sign of the numerator. Given that $0 \leq \phi \leq 1$, for values of $n \geq 2$, the partial derivative is positive. The greater the level of negative externalities, the higher the expenditure shifting. However, for $n = 1$, so that there is a single agency, the value of $\frac{\partial P_1}{\partial \phi}$ is initially positive, but for values of $\phi > (2 - \sqrt{2})$, the partial derivative becomes negative. Substituting ϕ and $n = 1$ into equation (18) indicates that where there is only one agency, and where the negative externalities on Policy 1 are 100%, there is no expenditure shifting.[xiv]

Figure 3: The informed monopoly and multi-agency target driven national equilibria



Again these results can be illustrated diagrammatically. Figure 3 is constructed so that $\alpha > 0.5$. As in Figure 1, the reaction to negative spillovers is represented by the equilibrium Policy Possibility Frontier, AC, with targets set at point T. However in this case the agencies are informed. Where there is only one monopoly agency, the loss minimising point is given as M, where the line AC is tangent to the iso-loss curve closest to T. As the number of agencies increase, the equilibrium moves along AC towards its limit, which equals point N.

Figure 3 also shows the equilibrium path as the spillover levels increase. We begin by considering the monopoly agency. Here the equilibrium path is the u-shaped curve that passes through T, M and X. We have commented already on its non-monotonic nature. For values of φ in the range $0 < \phi < (2 - \sqrt{2})$, as the negative spillover increases, there is expenditure shifting towards Policy 1. However, where $\phi > (2 - \sqrt{2})$, expenditure shifting is reduced and where $\phi = 1$, there is no expenditure shifting. The reason why the equilibrium expenditures on Policies 1 and 2 return to their initial ($\phi = 0$) levels where $\phi =$

1 is clear from Figure 3. Where there are 100% negative spatial spillovers, the Policy Production Frontier is the vertical straight line AXY0. This is tangent to the closest iso-loss line at X, where Q_2 is 1-α, its initial value with no spillovers.

At the other extreme, the multi-agency Nash equilibria, that is where there are a very large number of informed agencies, produce the path TNZ0.[xv] This has two distinct sections. The positively sloped 45° line, ZNT, is where the iso-loss functions have a slope of -1. However, Z is a corner solution, and at this point output of Policy 2 falls to zero. Subsequent increases in the negative spillovers result simply in further reductions in the output of Policy 1.

With an intermediate numbers of agencies (1 < n < ∞), the expenditure path will lie between these two extremes. The precise form is difficult to derive analytically. However, we do know that where the weighting of Policy 1 in the government's regional utility functions is greater than 0.5, as is the case represented in Figure 3, for values of $n > \frac{\alpha}{2\alpha - 1}$ there will be a value of ϕ within the range 0 < ϕ < 1 which gives a corner solution. For example, where α = 0.6 and n = 4, for negative spillover values greater than 0.92, the loss minimising value of Q_2 falls to zero, with a value of $Q_1 \leq 0.08$. For appropriately small values of $n\left(\leq \frac{\alpha}{2\alpha - 1}\right)$, the path would look like the curve YT, where the intercept on the vertical, Q_2 axis is $\frac{n-(2n-1)\alpha}{n}$.

If this analysis is extended to an infinitely repeated game, a sufficiently high discount factor produces a wide range of possible sub-game perfect Nash equilibria. In particular, under these circumstances an appropriate trigger strategy results in an outcome where the aggregate level of expenditure switching in each round equals that with a monopoly agency. An implicitly collusive outcome in this case effectively internalises the externality. However, with a large number of agencies, the co-ordination of such a strategy might be difficult without formal collusion. Whether the government would favour such an outcome is unclear and we discuss this in more detail in Section 9.

8. POSITIVE SPILLOVERS

In a target-driven regime with an uninformed principal, the impacts of positive and negative spillovers are quite different. Essentially positive spillovers make targets easier to achieve. In Figures 1 and 3 they pivot the equilibrium Policy Possibility Frontier (AC) outwards around A and mean that the target, T, is attainable for both informed and uninformed agencies. However, with positive spillovers, whilst some expenditure switching might occur, there are simultaneous adjustments to effort, so that in equilibrium the target outputs are always just met. Uninformed agencies will initially overshoot their targets and progressively reduce their effort as they approach the target from above, whilst informed agencies will adopt a Nash equilibrium strategy where all simultaneously reduce their effort in policy production.[xvi] However, because targets are met, the government is unaware of any spillover problem, and therefore misses potential welfare gains by setting undemanding targets.

9. WELFARE IMPLICATIONS

Previous sections simply consider the reaction of agencies to the policy spillovers, given the incentives embedded in the target-driven regime. We have not discussed the optimality of this reaction from the point of view of the principal (the government). This depends primarily on the nature of the government's regional utility function: that is, the specific characteristics of the relationship identified in equation (2).

From the government's perspective, the existence of unidentified negative spillovers creates three inter-related difficulties. First, the spillover changes the equilibrium trade-off between policies: in our chosen terminology, it alters the slope of the equilibrium Policy Production Frontier. The target set by an uninformed government therefore does not reflect the real trade-off between policy outputs. Second, the negative spillover makes existing targets unattainable, so that agency behaviour becomes driven by constrained loss minimization. However, the relevant iso-loss curves are likely to differ from the government's iso-utility curves. This implies that the agencies will react in ways that do not necessarily maximise the government's welfare. Third, the spillover is an externality not borne primarily by the individual agency that causes it and is therefore a likely further source of inefficiency. Increasing the number of informed agencies increases the extent of this externality.

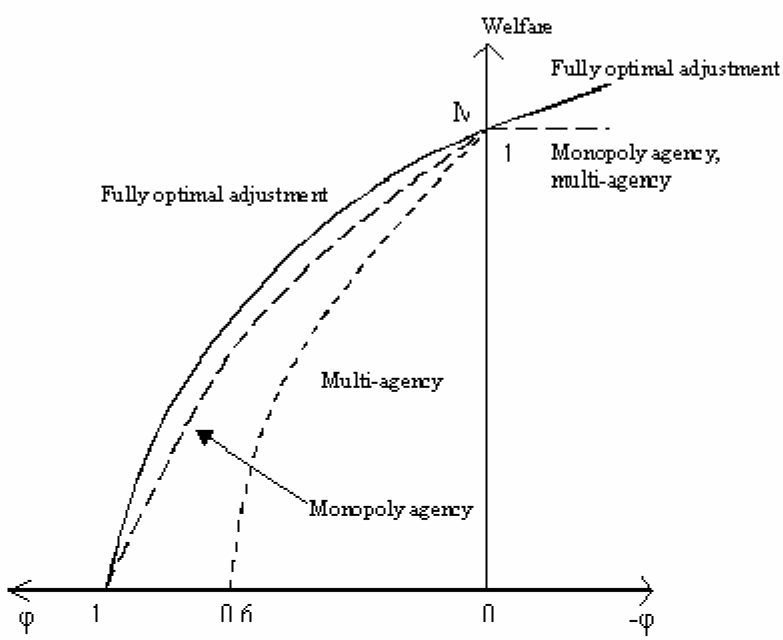
These problems seem inherent in the operation of "constrained discretion" in regional policy as presently applied in England.[xvii] If both government and agencies are uninformed, or if the agencies are informed but numerous, all three problems apply. One relevant question is whether a mechanism can be designed to deal with these problems in a decentralised manner. That is to say, even though the government is uninformed about the extent of policy spillovers, is there an incentive system that would lead the agencies to operate optimally? Such a system has three requirements. First, the agencies themselves have to be informed. Second, the incentives to agency chief executives must more fully reflect the government's regional utility function. Third, there must be a small number of agencies or agencies must collude in setting expenditure decisions, in order to fully internalise the spillover externality.

Such a policy regime would be very different from the target-driven procedures at present in operation in the UK. Two issues seem important. First, the incentive structure would make clear the government's trade-off between alternative policy outputs. But this is information that the government might not wish to make explicit (McVittie and Swales, 2003). Second, having a small number of large agencies is likely to reduce the effectiveness of decentralised decision making. As argued in Section 3, the direct effectiveness of policy is likely to require a large number of agencies, each with specific local knowledge. However, agency collusion – an alternative mechanism for internalising the externality - might run counter to other possible aims of a delegated policy delivery, such as the use of benchmark competition to reduce moral hazard.[xviii] In the next section we give an indication of the possible costs of operating the present target-driven system.

10. POLICY SIMULATIONS

In this section we report some illustrative policy simulations which indicate the possible size of the welfare losses associated with the target-driven regime, where by welfare losses we mean the sub-optimal adjustment to spillovers. Simulation results are reported for three different regional utility functions which have the same distribution parameter, α, but very different elasticities of substitution, indicated as σ here, between the policy outputs. In each Figure 4, 5 and 6, the variation in the optimal and target-constrained government welfare is given across a range of values of the spillover parameter, ϕ. In all three utility functions, the policy with the spatial spillover, Policy 1, has a weight (α) of 0.7. This implies that in all the cases under consideration, without the spillover the optimal policy outputs occur where 70% of expenditure is on Policy 1. More details are given in Appendix 5.

Figure 4: The variation in Cobb-Douglas utility by spillover level in different policy institutional settings



We begin with the results shown in Figure 4, which are for the Cobb-Douglas (unitary elasticity) utility function. For region i, this is shown as:

(2a) $$U_{C,i} = Q_{1,i}^{\alpha} Q_{2,i}^{1-\alpha}$$

where the C subscript indicates Cobb-Douglas. For each utility function we calculate the change in welfare where expenditure adjustments are determined by three alternative mechanisms. The first is the fully optimal adjustment (superscript F). This is the policy outcome that would maximise the welfare, and therefore be imposed by, a fully-informed government. The second is the target-driven adjustment made by a single informed (monopoly) agency (superscript M), as outlined in Section 7. The third is the target-driven adjustment determined by the Nash equilibrium with numerous informed agencies (superscript N). This is also the ultimate equilibrium adjustment made by uninformed agencies (of any number), as discussed in Section 6.

In each Figure, the government's welfare is standardised, taking a value of unity where there are no spillovers ($\phi = 0$). This implies that with no spillovers, the optimal operation of the policy gives a measured welfare value of unity for each regional utility function. Also, without spillovers, the actual and optimal operation of the policy is the same. Only where the government faces unknown spillovers do the optimal and target-driven outcomes differ.

First, Figure 4 shows that as the negative spillover level increases, the fully optimal adjustment shows lower welfare gains. This is a general result, given that the negative spillovers act to reduce the effectiveness of Policy 1.[xix] Further, for the Cobb-Douglas utility function, where the negative spillover parameter takes the value unity there are no possible welfare gains. This reflects the degree of complementarity between policy outputs with this functional form. Second, in this case, for negative spillovers the target-driven monopoly agency generates welfare results very close to the fully optimal adjustment. The monopoly agency internalises the spillover effects, so this result suggests that the iso-loss curves closely resemble the iso-utility curves under Cobb-Douglas.

Third, when the number of agencies is increased, the welfare results are much reduced for high negative spillovers and fall to zero for all values of $\phi \geq 0.6$. Finally, as discussed in Section 8, for positive spillovers the targeting-driven regimes perform badly because the agencies have no incentive to exploit the available efficiency benefits. The target-driven systems therefore return a standardised utility value of unity for any positive spillover values. This result applies to all the utility functions.

Figure 5: The variation in Leontief utility by spillover level in different policy institutional settings

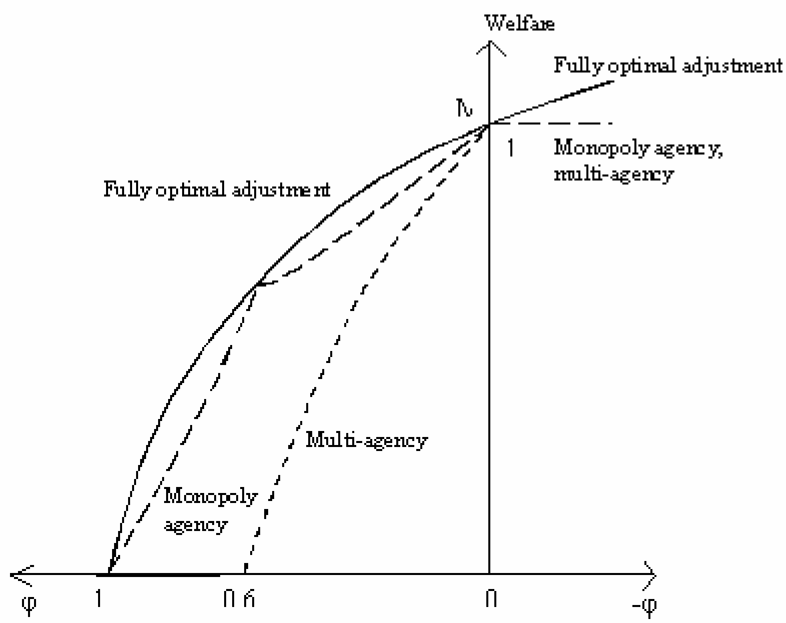


Figure 5 reports results from the same set of simulation, but for a regional utility function that has a fixed-coefficient (Leontief) specification. This corresponds to an elasticity of substitution of zero. The Leontief function takes the form:

(2b)
$$U_{L,i} = Min\left[\frac{Q_{1,i}}{\alpha}, \frac{Q_{2,i}}{1-\alpha}\right]$$

where the L subscript indicates the Leontief functional form. Given the lower degree of policy substitutability in the utility function, it is not surprising that with the fully optimal adjustment the welfare gain is lower than that with the Cobb-Douglas function for any value of ϕ apart from unity. Once more the monopoly agency performs with greater efficiency than the multiple agencies: the welfare from the Nash equilibrium with the multiple agencies again falls to zero when the output of Policy 2 hits zero for levels of $\phi \geq 0.6$. Clearly in these simulations the fact that informed multiple agencies fail to internalise the negative spillover has a major impact on the welfare results. Note too that even with the monopoly agency, the target-driven regime generates a level of welfare 10% lower than the fully optimal adjustment for negative spillover values between 0.3 and 0.5. However for values of $\phi \geq 0.6$, the welfare for the monopoly agency is in this case very close to optimal.[xx]

Figure 6: The variation in perfectly elastic utility by spillover level in different policy institutional settings.

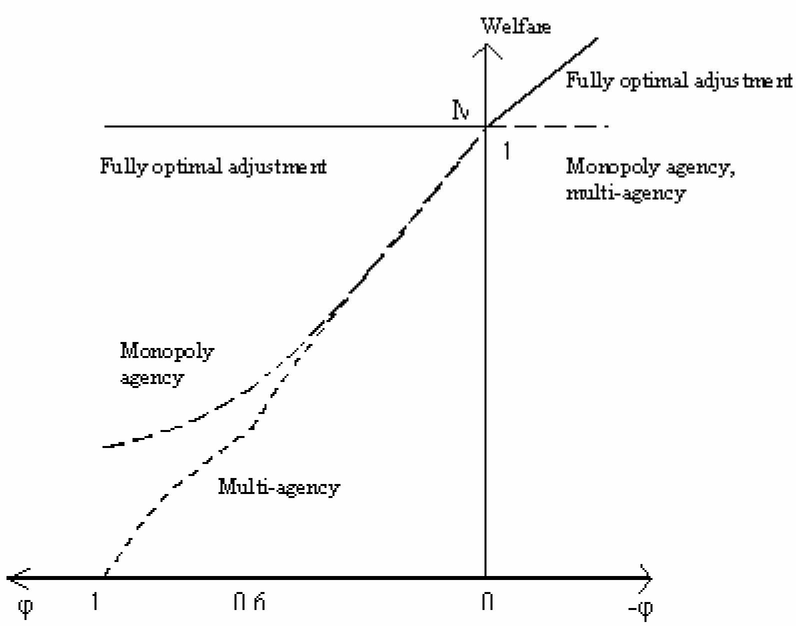


Figure 6 gives the results for a utility function that has perfect substitutability between policy outputs, so that $\sigma = \infty$. This implies a linear function which, given previous normalisation, is:

$$U_{P,i} = Q_1 + Q_2 \tag{2c}$$

where the P subscript implies perfect substitution. Here the optimal welfare is generally found at corner solutions. If there are negative spillovers ($\phi > 0$), the utility maximising response is to shift all expenditure to Policy 2 with no loss of utility. However if the spillovers are positive ($\phi < 0$), the shift is wholly to Policy 1, with utility increasing linearly with the positive spillover.

In Figure 6, the fully optimal adjustment gives a utility value of unity for all negative spillover values. This is because of the ability to perfectly substitute the non-spillover Policy 2. Therefore for even moderate negative spillovers, the efficiency loss in a target-driven regime is high. Where $\phi = 0.4$, welfare is over 30% less than optimal adjustment with both the monopoly and multi-agency equilibrium. The welfare level is always lower for the outcome with many agencies and the difference between the monopoly and multi-agency welfare result increases as the negative spillover increases.

In constructing Figure 6, we used the extreme example of a perfectly elastic utility function. However, if the regional utility function has an elasticity of substitution of any value greater than unity, then the optimal expenditure switching is still towards Policy 2. But as seen in Section 7, the target-driven regime always produces expenditure switching towards Policy 1. Clearly when the regional utility function has an elasticity greater than one, loss-minimisation in this target-driven system encourages inappropriate agency behavior.

The results given in Figures 4, 5 and 6 demonstrate that very serious efficiency losses can result where a principal, uninformed about potential spatial policy spillovers, imposes a decentralised and delegated target-driven regime. If the government is informed, however, then in principle these losses can be eliminated. Further, the fact that these impacts are external to the individual agencies that create them is not problematic. Where the development agencies are informed, the government can simply set the optimal attainable targets. Even where there are numerous agencies, the Nash equilibrium will now coincide with the targets. If agencies are uninformed, but the government sets a target equal to the optimal equilibrium outcome, the agencies will iterate towards this, as in Figure 2. Indeed, an informed government that knows the agencies to be uninformed, can get to the optimum immediately by setting the first period value for T_1, T_2 at $\frac{\alpha}{n}, \frac{(1-\alpha)}{n}$ and the second period values at $\frac{(1-\phi)\alpha}{n}, \frac{(1-\alpha)}{n}$.

It is important to note that the development agencies benefit if the government is informed, at least about the existence of negative spillovers. From the point of view of the development agencies, this means that the government can set attainable targets. However, in a cheap-talk game, it is in the interests of the agencies to underestimate positive and overestimate negative spillovers (Gibbons, 1992). The government therefore requires an independent source of information for the extent of spatial spillovers, even if the agencies are informed.

11. CONCLUSION

The UK government argues that the target-driven decentralised and delegated delivery of English regional policy is an extension of the "constrained discretion" model used so effectively in the operation of monetary policy (Balls, 2002; Bernanke and Mishkin, 1997, McVittie and Swales, 2004a). However, for the government to be able to operate such an arms-length delegated policy effectively, the appropriate institutional and informational framework needs to be put in place (Balls *et al*, 2002; North, 1990).

We argue that at present information on spatial spillovers from regional policy is extremely limited. Our simplified model suggests that such government ignorance distorts policy expenditures and can considerably constrain policy effectiveness. Whilst it is possible to construct decentralised mechanisms to deal with these problems, such mechanisms have associated difficulties. If the government is to continue with its present decentralised target-driven system for regional regeneration, there is a strong *prima facie* argument for independent information on the nature and extent of spatial policy spillovers.

APPENDIX 1: OPTIMAL POLICY EXPENDITURES WHERE THE REGIONAL UTILITY FUNCTION IS COBB-DOUGLAS, WITH NO SPILLOVERS

For Cobb-Douglas regional utility functions, that is, where equation (2) in the text takes the form (2a), the maximisation problem is:

(A1.1)

$$Max\ L_{P_{i,1}B_i} = W((\gamma_1 P_{1,1})^{\alpha}(\gamma_2(B_1 - P_{1,1}))^{1-\alpha}, \ldots, ((\gamma_1 P_{1,n})^{\alpha}(\gamma_2(B_n - P_{1,n}))^{1-\alpha}) - \lambda\left(1 - \sum B_i\right)$$

which implies that:

(A1.2)
$$\frac{\partial L}{\partial P_i} = \frac{\partial W}{\partial U_i}\left[\gamma_1^{\alpha}\gamma_2^{1-\alpha}\left[\alpha\left[\frac{B_i - P_{1,i}}{P_{1,i}}\right]^{1-\alpha} - (1-\alpha)\left[\frac{P_{1,i}}{B_i - P_{1,i}}\right]^{\alpha}\right]\right] = 0 \qquad \forall_i$$

(A1.3)
$$\frac{\partial L}{\partial B_i} = \frac{\partial W}{\partial U_i}\left[\gamma_1^{\alpha}\gamma_2^{1-\alpha}(1-\alpha)\left[\frac{P_{1,i}}{B_i - P_{1,i}}\right]^{\alpha}\right] - \lambda = 0 \qquad \forall_i$$

(A1.4)
$$\frac{\partial L}{\partial \lambda} = 1 - \sum B_i = 0$$

From (A1.2), given that $\frac{\partial W}{\partial U_i}, \gamma_1, \gamma_2 > 0$,

(A1.5)
$$\frac{P_{1,i}}{B_i - P_{1,i}} = \frac{\alpha}{1-\alpha} \qquad \forall_i$$

Substituting (A1.5) into equation (A1.3) produces:

(A1.6)
$$\frac{\partial W}{\partial U_i} = \frac{\lambda}{\gamma_1^{\alpha}\gamma_2^{1-\alpha}\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \qquad \forall_i$$

Given the symmetry and concavity of the welfare function, expression (A1.6) implies that the utility in each region is the same. Given (A1.5) this means that B_i and P_i do not vary across regions. Therefore, from (A1.4), and given that there are n regions:

(A1.7) $$B_i = \frac{1}{n} \qquad \forall_i$$

Substituting (A1.7) into (A1.5) gives

(A1.8) $$P_{1,i} = \frac{\alpha}{n}, \quad P_1 = \alpha$$

Therefore the weight of Policy 1 in the government's welfare function is α. Substituting (A1.7) and (A1.8) into the welfare function gives:

(A1.9) $$W = W\left[\left[\gamma_1^{\alpha}\gamma_2^{1-\alpha}\left[\frac{\alpha}{n}\right]^{\alpha}\left[\frac{1-\alpha}{n}\right]^{1-\alpha}\right],\ldots,\left[\gamma_1^{\alpha}\gamma_2^{1-\alpha}\left[\frac{\alpha}{n}\right]^{\alpha}\left[\frac{1-\alpha}{n}\right]^{1-\alpha}\right]\right]$$

APPENDIX 2: THE DYNAMIC MOVEMENT TO EQUILIBRIUM WITH UNINFORMED AGENCIES

In a repeated game with negative spatial spillovers and uninformed agencies, equation (3) in the text (with γ_1=1) is replaced by equation (A2.1) for $E(Q_{1,i,t})$, the expected output of Policy 1 in region i in time period t:

$$\text{(A2.1)} \qquad E(Q_{1,i,t}) = P_{1,i,t} - E(K_{1,i,t})$$

where the term $E(K_{1,i,t})$ is the expected value of the negative shock to Policy 1. This shock is interpreted by the uninformed agencies as exogenous and its expected value in time period t is equal to its actual value in the previous time period. However, the policy effectiveness shock is actually caused by negative spillovers, so that:

$$\text{(A2.2)} \qquad E(K_{1,i,t}) = K_{1,i,t-1} = \frac{\phi}{n}\sum_{j=1}^{n} P_{1,j,t-1}$$

Giving expression (9) in the text - the expression for the loss function - a negative sign and using equation (A2.1) for the expected output of Policy 1, the Lagrangean to determine the minimum expected loss takes the form:

$$\text{(A2.3)}\; M\text{ax}\, L_{P_{1,i,t},P_{2,i,t},\lambda} = -(P_{1,i,t} - T_{1,i} - E(K_{1,i,t}))^2 - (P_{2,i,t} - T_{2,i})^2 + \lambda\left(\frac{1}{n} - P_{1,i,t} - P_{2,i,t}\right)$$

If the budget constraint binds, as it does in this case, the Lagrangian is maximised where:

$$\text{(A2.4)} \qquad P_{1,i,t} = \frac{1+n(T_{1,i} - T_{2,i} + E(K_{1,i,t}))}{2n}, \quad P_{2,i,t} = \frac{1-n(T_{1,i} - T_{2,i} + E(K_{1,i,t}))}{2n}$$

For the targets $T_{1,i} = \frac{\alpha}{n}, T_{2,i} = \frac{1-\alpha}{n}$, expression (A2.4) gives:

(A2.5) $$P_{1,i,t} = \frac{\alpha}{n} + \frac{E(K_{1,i,t})}{2}, \quad P_{2,i,t} = \frac{1-\alpha}{n} - \frac{E(K_{1,i,t})}{2}$$

Using equation (A2.2) and the result that all regions will act symmetrically, equations (A2.5) can be restated as the difference equations:

(A2.6) $$P_{1,i,t} = \frac{\alpha}{n} + \frac{\phi P_{1,i,t-1}}{2}, \quad P_{2,i,t} = \frac{1-\alpha}{n} - \frac{\phi P_{1,i,t-1}}{2} \qquad \forall i$$

APPENDIX 3: THE ADJUSTMENT FOR UNINFORMED AGENCIES

For Policy 2, the changes in the output and expenditure after the adjustment are equal, as the efficiency parameter γ_2 is constant and calibrated to unity. Therefore from equation (12) in the text, the change in the regional output for Policy 2, $\Delta Q_{2,i}$ is given as:

$$\Delta Q_{2,i} = -\frac{\alpha\phi}{n(2-\phi)} \qquad \forall_i \tag{A3.1}$$

To calculate the change in output of Policy 1, we use equation (11) in the text for the new equilibrium expenditure and equation (8) for the equilibrium efficiency parameter with the negative spillovers. This produces:

$$\Delta Q_{1,i} = P_{1,i}^{e}(1-\phi) - \frac{\alpha}{n} = \frac{2\alpha(1-\phi)}{n(2-\phi)} - \frac{\alpha}{n} = -\frac{\alpha\phi}{n(2-\phi)} = \Delta Q_{2,i} \qquad \forall_i \tag{A3.2}$$

Equations (A3.2) shows that the change in both policy outputs is the same, so that the equilibrium lies on line TD, positively sloped 45° line through T.

APPENDIX 4: THE NASH EQUILIBRIUM WITH INFORMED AGENTS

(A4.1) $$M\,\text{ax}\, L_{P_{1,i},P_{2,i},\lambda} = -\left(P_{1,i} - \frac{\phi}{n}\sum_{j=1}^{n} P_{1,j} - T_{1,i} \right)^2 - (P_{2,i} - T_{2,i})^2 + \lambda\left(\frac{1}{n} - P_{1,i} - P_{2,i} \right) \quad \forall_i$$

(A4.2) $$\frac{\partial L}{\partial P_{1,i}} = -2\left[\frac{n-\phi}{n} \right]\left[P_{1,i} - \frac{\phi}{n}\sum_{j=1}^{n} P_{1,j} - T_{1,i} \right] + \lambda = 0 \qquad \forall_i$$

(A4.3) $$\frac{\partial L}{\partial P_{2,i}} = -2\left[P_{2,i} - T_{2,1} \right] + \lambda = 0 \qquad \forall_i$$

(A4.4) $$\frac{\partial L}{\partial \lambda} = \frac{1}{n} - P_{1,i} - P_{2,i} = 0 \qquad \forall_i$$

Substituting (A4.3) and (A4.4) into (A4.2) gives:

(A4.5) $$\left[\frac{n-\phi}{n} \right]\left[\frac{(n-\phi)}{n} P_{1,i} - \frac{\phi}{n}\sum_{i \neq j} P_{1,j} - T_{1,i} \right] = \frac{1}{n} - P_{1,i} - T_{2,i} \qquad \forall_i$$

Rearranging (A4.5) gives the reaction function given in the text as equation (15):

(A4.6) $$P_{1,i} = \frac{n + n(n-\phi)T_{1,i} - n^2 T_{2,i}}{(n-\phi)^2 + n^2} + \frac{(n-\phi)\phi\sum_{j \neq i} P_{1,j}}{(n-\phi)^2 + n^2} \qquad \forall_i$$

Substituting the values $\frac{\alpha}{n}, \frac{1-\alpha}{n}$ for $T_{1,i}$, $T_{2,i}$

(A4.7) $$P_{1,i} = \frac{n + \alpha(n-\phi) - n(1-\alpha)}{(n-\phi)^2 + n^2} + \frac{(n-\phi)\phi\sum_{j \neq i} P_{1,j}}{(n-\phi)^2 + n^2} \qquad \forall_i$$

Summing (A4.7) across all regions gives

(A4.8) $$P_1 = \sum_{i=1}^{n} P_{1,i} = \frac{n + (n-\phi)\alpha - n(1-\alpha)}{n(2-\phi) + \phi^2 - \phi} = \frac{(2n-\phi)\alpha}{n(2-\phi) + \phi^2 - \phi}$$

APPENDIX 5: THE FULLY OPTIMAL ADJUSTMENT AND TARGET-DRIVEN VALUES FOR COBB-DOUGLAS, LEONTIEF AND PERFECTLY ELASTIC REGIONAL UTILITY FUNCTIONS.

In this appendix we calculate the relationship between the optimal full-information and the target-driven constrained regional utility values. There are two sets of target-driven figures, both for informed agencies. One is where there is a single monopoly agency, so that all externalities are internalised. The other is the Nash equilibrium where there are numerous agencies.

We compare the results using three regional utility functions: Cobb-Douglas, fixed-coefficients (Leontief) and the perfectly elastic, identified by the subscripts C, L and P. These correspond to elasticities of substitution between $Q_{1,i}$ and $Q_{2,i}$ in the regional utility functions (equation (2) of the text) of unity, zero and infinity respectively. They are represented by equations (2a), (2b) and (2c) in the text

We go through each informational/institutional set up in turn. We first determine policy outputs (the values of $Q_{1,i}$ $Q_{2,i}$). We then value them by substitution into the alternative regional utility functions.

A5.1 Fully optimal adjustment

We begin by finding the maximum value for the functions, given a national budget constraint, B, values of the two efficiency parameters, γ_1, γ_2, and the spillover, φ. We are particularly interested in the way that this value varies with φ.

The fully optimal adjustment welfare value, U^F, can be expressed generally as:

(A5.1) $$U_i^F = U_i^F(B_i, \gamma_1, \gamma_2, \alpha, \phi)$$

In the text we have normalised the problem by setting the values of parameters γ_1 and γ_2 and the national budget at unity. There are n identical regions, so that the regional budget is $\frac{1}{n}$. Of course, the appropriate value for (A4.1) will depend on the nature of the utility function. Again this identified subsequently through a subscript.

A5.1.1 Cobb-Douglas

Following the method adopted in Appendix 1, for a Cobb-Douglas utility function, the maximum full-information regional utility for each region equals:

(A5.2) $$U_{C,i}^{F} = \frac{\alpha^{\alpha}(1-\alpha)^{1-\alpha}(1-\phi)^{\alpha}}{n}$$

This would be the utility, for example, that would be attained if the government could set optimal regional targets. These targets would be $\frac{\alpha(1-\phi)}{n}, \frac{1-\alpha}{n}$. In order to compare the impact of spillovers across different regional utility functions and targeting regimes, in each case we express the utility level as an index, where the utility value with no spillovers is unity. This is consistent with our assumption that the government sets targets that are optimal for the case where φ = 0. From (A5.2), the utility with no spillovers, $\bar{U}_{C,i}$, is given as:

(A5.3) $$\bar{U}_{C,i}^{F} = \frac{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}{n}$$

Therefore the relative value is:

(A5.4) $$\frac{U_{C,i}^{F}}{\bar{U}_{C,i}} = (1-\phi)^{\alpha}$$

A5.1.2 Leontief

The corresponding calculation for the Leontief case is made in the following way. The locus of input combinations with the Leontief fixed coefficients is a straight line through the origin passing through the point (α, 1-α). This is represented by the function:

(A5.5) $$Q_{2,i} = \left[\frac{1-\alpha}{\alpha}\right] Q_{1,i}$$

Further, the equilibrium Policy Possibility Frontier (line AC in Figures 1 and 3) is given by::

(A5.6) $$\frac{Q_{1,i}}{1-\phi} + Q_{2,i} = \frac{1}{n}$$

Substituting (A5.5) into (A5.6) and solving for $Q_{1,i}$ gives:

(A5.7) $$Q_{1,L,i}^{F} = \frac{\alpha(1-\phi)}{(1-\phi(1-\alpha))n}$$

From equation (2b) in the text, the unconstrained maximum value for the Leontief utility function is therefore:

(A5.8) $$U_{L,i}^{F} = \frac{Q_{1,i}}{\alpha} = \frac{1-\phi}{(1-\phi(1-\alpha))n}$$

Again we standardise this utility measure by expressing it as a ratio of the value with no spillovers. This value is given by:

(A5.9) $$\bar{U}_{L,i}^{F} = \frac{1}{n}:$$

so that

$$\text{(A5.10)} \qquad \frac{U^F_{L,i}}{\bar{U}^F_{L,i}} = \frac{1-\phi}{(1-\phi(1-\alpha))}$$

A5.1.3 Perfectly elastic

With the perfectly elastic regional utility function, we are always driven to corner solutions. Where there are negative spillovers, the optimal position for the government is to switch expenditure solely to Policy 2, so that for $\varphi \geq 0$

$$\text{(A5.11)} \qquad Q^F_{1,P,i} = 0, \quad Q^F_{2,P,i} = \frac{1}{n}$$

From equation (2c)

$$\text{(A5.12)} \qquad U^F_{P,i} = \frac{1}{n}$$

and

$$\text{(A5.13)} \qquad \bar{U}^F_{P,i} = \frac{1}{n}$$

so that

$$\text{(A5.14)} \qquad \frac{U^F_{P,i}}{\bar{U}^F_{P,i}} = 1$$

However, when there are positive spillovers, the government should shift all expenditure to Policy 1, so that where $\varphi < 0$:

(A5.15) $$Q^F_{1,P,i} = \frac{1-\phi}{n}, \quad Q^F_{2,P,i} = 0$$

Equations (2c), (A5.13) and (A5.15) imply that

(A5.16) $$\frac{U^F_{P,i}}{\bar{U}^F_{P,i}} = 1-\phi\,.$$

A5.2 Nash equilibrium with many agents

Where welfare is additionally constrained by a targeting mechanism, a government uninformed about spatial policy spillovers, and a large number of delegated agencies, so that $n \rightarrow \infty$, there are three cases:

Case 1. $\alpha \le \frac{1}{2}, 1 \ge \phi \ge 0$

Policy outputs are given at the intersection of the equilibrium Policy Production Frontier and the locus of Nash Equilibria. The Policy Production Frontier is given by equation (A5.6), whilst the locus of Nash Equilibria (line DT in Figure 3) takes the form:

(A5.17) $$Q_{2,i} = Q_{1,i} + Z$$

where Z is a constant. However, where $Q_{1,i} = \frac{\alpha}{n}, Q_{2,i} = \frac{1-\alpha}{n}$, so that substituting these values into equation (A5.17) gives $Z = \frac{1-2\alpha}{n}$, so that the locus of Nash equilibria becomes:

(A5.18) $$Q_{2,i} = Q_{1,i} + \frac{1-2\alpha}{n}$$

Solving simultaneously for equations (A5.6) and (A5.18) and rearranging gives:

(A5.19) $$Q_{1,i}^N = \frac{2\alpha(1-\phi)}{(2-\phi)n}, Q_{2,i}^N = \frac{2(1-\alpha)-\phi}{(2-\phi)n}$$

For situations fitting this case, we substitute the policy outputs given by expressions (A5.19).

Case 2. $\alpha > \frac{1}{2}, 1 \geq \phi \geq 0$

If the value of $\alpha > \frac{1}{2}$, then for some feasible values of the negative externality, ϕ, the loss-minimising policy outputs for the regional agency take a corner solution. Specifically, the output of Policy 2 falls to zero. Substituting $Q_{2,i} = 0$ into the locus of Nash equilibria given by equation (A5.19) implies that this occurs where:

(A5.20) $$\phi = 2(1-\alpha)$$

Therefore, where $\phi < 2(1-\alpha)$, policy outputs are given as in expression (A5.19). However, where $\phi \geq 2(1-\alpha)$, policy outputs are given as:

(A5.21) $$Q_{1,i}^N = \frac{1-\phi}{n}, \quad Q_{2,i}^N = 0$$

Case 3: $\phi < 0$

As we argue in Section 8 of the text, where there are positive spillovers, the agencies will simply deliver the target outputs. Therefore, where the value of ϕ lies in this range, the value of $\frac{U_i^N}{\bar{U}_i^N}$ is unity, independently of the form of the regional utility function.

A5.2.1 Cobb-Douglas

Case 1:

Substituting the expressions for $Q_{1,i}$ and $Q_{2,i}$ from (A5.19) into the Cobb-Douglas utility function (equation 2a in the text) produces:

(A5.22) $$U_{C,i}^{N} = \frac{(2\alpha(1-\phi))^{\alpha}(2(1-\alpha)-\phi)^{1-\alpha}}{n(2-\phi)}$$

The regional utility with no spillovers is shown in equation (A5.3), so that standardising against the value where spillovers are zero gives:

(A5.23) $$\frac{U_{C,i}^{N}}{\overline{U}_{C,i}^{N}} = \frac{(2(1-\phi))^{\alpha}(2(1-\alpha)-\phi)^{1-\alpha}}{(2-\phi)(1-\alpha)^{1-\alpha}}$$

Case 2:

Where $\phi < 2(1-\alpha)$, the expression is the same as (A5.23), and where $\phi \geq 2(1-\alpha)$ substituting the policy outputs given in (A5.21) into equation (A5.1) produces:

(A5.24) $$\frac{U_{C,i}^{N}}{\overline{U}_{C,i}^{N}} = 0\,.$$

Case 3:

(A5.25) $$\frac{U_{C,i}^{N}}{\overline{U}_{C,i}^{N}} = 1$$

A4.2.2 Leontief

Case 1:

The value for a fixed-coefficients, Leontief, utility function is found by substituting the expressions for $Q_{1,i}$ and $Q_{2,i}$ from (A5.19) into equation (2b) in the text. This gives:

(A5.26) $$U_{L,i}^{N} = Min\left[\frac{2(1-\phi)}{(2-\phi)n}, \frac{2(1-\alpha)-\phi}{(2-\phi)(1-\alpha)n}\right]$$

The regional utility with no spillovers is shown in equation (A5.9), so that the standardised regional utility takes the form:

(A5.27) $$\frac{U_{L,i}^{N}}{\overline{U}_{L,i}^{N}} = Min\left[\frac{2(1-\phi)}{(2-\phi)}, \frac{2(1-\alpha)-\phi}{(2-\phi)(1-\alpha)}\right]$$

Case 2:

Where $\phi < 2(1-\alpha)$, the expression is the same as (A5.27), and where $\phi \geq 2(1-\alpha)$ if the policy outputs given in (A5.21) are substituted into equation (2b) in the text, this generates:

(A5.28) $$\frac{U_{L,i}^{N}}{\overline{U}_{L,i}^{N}} = 0\,.$$

Case 3:

(A5.29) $$\frac{U_{L,i}^{N}}{\overline{U}_{L,i}^{N}} = 1$$

5.2.3 Perfectly elastic

Case 1:

The value for a perfectly elastic regional utility function is found by substituting the expressions for $Q_{1,i}$ and $Q_{2,i}$ from (A5.19) into equation (2c) in the text. This gives:

(A5.30) $$U_{P,i}^{N} = \frac{2(1-\alpha\phi)-\phi}{(2-\phi)n}$$

Combining this with equation (A5.13) where there are no spillovers gives the standardised regional utility:

(A5.31) $$\frac{U_{P,i}^{N}}{\bar{U}_{P,i}^{N}} = \frac{2(1-\alpha\phi)-\phi}{2-\phi}$$

Case 2:

Where $\phi < 2(1-\alpha)$, the expression is the same as (A5.31). However, where $\phi \geq 2(1-\alpha)$ we substitute the values given in (A5.21) to produce:

(A5.32) $$\frac{U_{P,i}^{N}}{\bar{U}_{P,i}^{N}} = \frac{2\alpha(1-\phi)}{2-\phi}$$

Case 3:

(A5.33) $$\frac{U_{P,i}^{N}}{\bar{U}_{P,i}^{N}} = 1$$

A5.3 Monopoly agency

Because there is only one agency for this set of outcomes, we can drop the regional subscript. For the monopoly agency we consider two spillover ranges: these are simply whether spillovers are positive or negative.

Case 1: $1 \geq \phi \geq 0$*:*

The policy outputs of the monopoly agent can be derived using equation (16) in the text. Substituting n =1, the output of Policy 1 is derived as:

(A5.34) $$Q_1^M = (1-\phi)P_1 = \frac{(2-\phi)(1-\phi)\alpha}{2(1-\phi)+\phi^2} > 0$$

The output of Policy 2 can be determined from equation (16) and the budget constraint as:

(A5.35) $$Q_2^M = 1 - P_1 = 1 - \frac{(2-\phi)\alpha}{2(1-\phi)+\phi^2} = \frac{2(1-\phi)+\phi^2-(2-\phi)\alpha}{2(1-\phi)+\phi^2}$$

As with the Nash equilibrium with numerous agencies, corner solutions are possible here though rather more difficult to identify analytically. The denominator in (A5.35) is positive (for $0 \leq \phi \leq 1$). Therefore the sign of Q^M_2 depends on the sign of the numerator. Setting the numerator on the RHS of equation (A5.35) to zero (so that Q_2 is also zero) and rearranging gives the range of values for α which will generate a negative loss-minimising value for Q^M_2::

(A5.36) $$\alpha \geq \frac{2(1-\phi)+\phi^2}{2-\phi}.$$

From trial and error, there are clearly combinations of α and ϕ within the range $1 \geq \alpha, \phi \geq 0,$ where expression (A5.36) will hold. For example, if $\phi = \frac{1}{2}$, any values of α above $\frac{5}{6}$ will generate such a result. The numerical calculations that serve as the basis for Figures 4, 5 and 6 in the text do not generate corner solutions. However, where such corner solutions occur, the results are as in the corresponding solutions reported under Case 2 for the Nash equilibria with numerous agencies. That is to say, if constraint (A5.36) holds, the appropriate policy outputs are:

(A5.37) $$Q_1^M = 1 - \phi, \quad Q_2^M = 0$$

Case 2: $\phi < 0$

As for the Nash equilibrium, where there are positive spillovers the monopoly agency will simply hit the target, so that $U^M = \bar{U}^M$.

5.3.1 Cobb-Douglas

Case 1:

Discounting corner solutions, the utility level for the monopoly agency case with a Cobb-Douglas utility function can be found by substituting (A5.34) and (A5.35) into equation (2a) in the text, producing:

(A5.38) $$U_C^M = \frac{\left[(2-\phi)(1-\phi)\right]^{\alpha} \alpha^{\alpha} \left[2(1-\phi) + \phi^2 - (2-\phi)\alpha\right]^{1-\alpha}}{2(1-\phi) + \phi^2}$$

Expressing this utility as a ratio of the value with no spillovers, given by (A5.3), produces:

(A5.39) $$\frac{U_C^M}{\bar{U}_C^M} = \frac{\left[(2-\phi)(1-\phi)\right]^{\alpha}\left[2(1-\phi)+\phi^2-(2-\phi)\alpha\right]^{1-\alpha}}{(2(1-\phi)+\phi^2)(1-\alpha)^{1-\alpha}}$$

Case 2:

(A5.40) $$\frac{U_C^M}{\bar{U}_C^M} = 1$$

5.3.2 Leontief

Case 1:

Again, discounting corner solutions, the standardised utility level for the monopoly agency case with a Leontief utility function can be found by substituting (A5.34) and (A5.35) into equation (2b) of the text and using (A5.9) as the zero spillover value, producing:

(A5.41) $$\frac{U_L^M}{\bar{U}_L^M} = Min\left[\frac{(2-\phi)(1-\phi)}{2(1-\phi)+\phi^2}, \frac{2(1-\phi)+\phi^2-(2-\phi)\alpha}{\left[2(1-\phi)+\phi^2\right](1-\alpha)}\right]$$

Case 2:

(A5.42) $$\frac{U_L^M}{\bar{U}_L^M} = 1$$

5.3.3Infinitely elastic

Case 1:

Discounting corner solutions, the standardised utility level for the monopoly agency case with an infinitely elastic utility function can be found by substituting (A5.34) and (A5.35) into equation (2c) of the text and using (A5.13) to give the zero spillover value generates:

(A5.43) $$\frac{U_P^M}{\bar{U}_P^M} = \frac{2(1-\phi(1+\alpha))+\phi^2(1+\alpha)}{2(1-\phi)+\phi^2}$$

Case 2:

(A5.44) $$\frac{U_P^M}{\bar{U}_P^M} = 1$$

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END NOTES

[i] In this paper the terms "local" and "regional" are used synonymously. Local does not here imply a higher level of geographic disaggregation than regional.

[ii] At the time of writing, the devolved institutions in Northern Ireland are temporarily suspended and funding currently flows through the Northern Ireland Office. Additionally, the Scottish Parliament has limited independent tax-raising powers.

[iii] The government has introduced other institutional arrangements for monitoring and controlling English RDAs, alongside targets. Whilst these other mechanisms are generally given a lower profile in government documents, their true significance is probably underestimated (McVittie and Swales, 2004b).

[iv] The reason for limiting the regional utility functions is explained later. See footnote 5.

[v] The linear homogeneity of the regional utility function is required here.

[vi] In these simulations the impact on Scotland and the UK as a whole is positive but the effect on that part of the UK outwith Scotland is negative.

[vii] Positive spillovers are reported in Fingleton (2003) and in some of the simulations over some of the time periods in Ferguson *et al* (2004).

[viii] We have the spillover linked to policy expenditure, rather than output, for pedagogic reasons – it removes one level of endogeneity. Such spillovers might occur where there are scarce inputs. An example would be competing for inward investment, with a limited supply of potential mobile plants.

[ix] Whether this function adequately captures the behaviour of agencies facing numerous targets is at present unclear. It will be of interest to test this empirically once sufficient data become available.

[x] There is some uncertainty here. In general one would think that over-performing development agencies would be positively valued. However, a key PSA target for the present government is to reduce growth differentials between regions (HM Treasury, 2004). This seems to imply that if high growth regions over-perform, that this would be unwelcome, though we have never seen this point explicitly discussed in the official literature on targets as applied in this context.

[xi] A formal demonstration that the equilibrium lies on line TD is given in Appendix 3.

[xii] A fuller derivation is given in Appendix 4.

[xiii] The equality holds in expression (19) at the two extreme values for φ, zero and unity. The zero case, where there are no spillovers, has been discussed already. We shall deal with the unity case presently.

[xiv] In the past, HM Treasury argued that employment orientated regional policy generated 100% crowding out at the national level, though this is no longer their position, at least as far as supply side policies are concerned (HM Treasury, 2003).

[xv] Subsequently where we use the term multi-agency Nash equilibrium or multi-agency case, we are using this to indicate situations where the number of agencies is very large so that $n \rightarrow \infty$.

[xvi] A fuller analysis needs to specify in more detail the nature of the cost of effort for the development agencies.

[xvii] Recall that in Northern Ireland, Scotland and Wales, local regeneration policy is devolved.

[xviii] At present the government encouraged some co-operation between RDAs but apparently in an *ad hoc* manner. An example is the Northern Way initiative, supported by the Office of the Deputy Prime Minister (2004).

[xix] Strictly the general result is that the impact on the welfare gain is non-positive, as can be seen in the example of a perfectly elastic utility function illustrated in Figure 6.

[xx] For the Leontief case, if each policy has equal weight ($\alpha = ½$), then the outcome for negative spillovers with a large number of informed agencies is welfare maximising. Both the locus of

Nash equilibria and the utility maximising adjustment path are positively-sloped 45° lines through the origin.