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An Empirical Inquiry of the Efficiency of Intergovernmental Transfers for Water Projects Based on the WRDA Data

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Abstract

The aim of this paper is to check whether intergovernmental transfers for water projects accepted in 1986 can be rationalized by a simple efficiency criterion. The empirical findings support this conjecture only partially.

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1. Motivation

Public spending, its size and composition, has been studied extensively in the public finance literature. The choice of fiscal institutions that can successfully restrict government spending is one of the central issues in the European Monetary Integration debate. As a result, the analysis of alternative budget rules has received considerable attention in the literature. [1] Substantial interest in the topic arose in the U.S. in the middle of 1980's, when the size of the government deficit became alarming. One of the steps taken towards spending reduction was the Water Resource and Development Act 1986 (WRDA'86). This act changed cost sharing arrangements for water projects. Instead of being covered entirely from the Federal revenues, construction costs for these projects had to be shared between the local and federal interests. There is evidence suggesting that the new rules lead to lower spending on water projects, see DelRossi and Inman (1998).

Clearly, the amount of spending is not the best indicator of the government quality. Not only the size, but also the effect of spending has to be considered in order to make judgments about desirable features of government organization. This paper focuses on efficiency evaluation of government policies.

Traditional approach to this evaluation is cost-benefit analysis.[2] One of the main obstacles limiting the applicability of this method is the absence of a reliable way to estimate the demand for public projects. This demand is necessary to elicit the taxpayers' willingness to pay for the project that has to be compared with the amount actually paid for it, or its cost. To overcome the obstacle I will concentrate on a particular type of public spending, water projects and only those devoted to harbor development (navigation) and flood control. Moreover, evaluating the effect of the projects **after** their construction allows to get a more precise estimate of the willingness to pay directly from the market indicators without the

[1] See Persson and Tabellini (2000) for the theoretical perspective, see von Hagen (1992) for the empirical analysis of the relationship between budget formation rules and the size of the budget.

[2] See Mishan (1976).

usual difficulties associated with the evaluation of the future benefits.[3]

In practice the choice of water projects is monitored by the United States Army Corps of Engineers (the Corps) performing cost benefit analysis. Only those projects that have the benefit above the costs can be considered by the legislature. There is a wide spread presumption that the Corps, being both the experts and the potential contractors, may have a tendency towards the choice of bigger projects overestimating their benefits.[4] This paper provides an independent efficiency test for the water projects.

Roughly speaking, it is devoted to the question of whether the cost sharing between federal and local interests for water projects motivate local representatives in the federal legislature to choose projects that are in the "best national interest". The national objective (public welfare) will be defined in terms of aggregate benefits and costs generated by the project, and thus, it is invariant to the distributional aspects of the choice.[5] It true that social equity concerns may affect water management policies, and some of the intergovernmental grants, in general, are inherently "equalizing".[6] However, equity considerations can be hardly seen as a core motivation behind federal transfers for water projects. Thus, it is natural to concentrate on efficiency.

1.1. Brief Historical Background

The rules governing federal subsidies for water projects in the U.S. have been modified over the course of its long history. Would it be irrigation in the West or waterways improvement,

[3]See Maass (1962) for the suggested methodology for designing and estimating the benefits from water projects to be.

[4]See Maass (1951).

[5]Under certain conditions (some degree of) redistribution may be optimal, if the social welfare is maximized "ex-ante", prior to lifting Harsanyi/Rawlsian's "veil of ignorance" that conceals the identity and the status of each society member. In this sense concern for equity itself can be rationalized based on efficiency considerations. In this paper though, the social objective is formulated "ex-post".

[6]German Constitution, for example, contains explicit rules of computing the equalizing grants (see Finer, Bogdanor, and Rudden (1995)). As for the US, see Inman (1988) for the evidence that federal aid in the U. S. partially offsets unequal (across states) spending on education and infrastructure in the period of 1952-1984. The offset is complete for welfare spending in 1972-1984.

construction of a seaport or a dam, financial participation of the federal government grew substantially during the century preceding the Water Resource and Development Act 1986.[7] In fact, by that time all the construction costs for the water projects passed by Congress were covered by the federal transfer, while local residents were only responsible for the relocation costs (value of land, easements, rights-of-way, and all alterations and relocations of utilities, streets, bridges, buildings and other structures and improvements, and dredge disposal).[8] This, probably, in part, reflected the fact that water projects were viewed to be of national importance.

The discussion about creating a reliable and a duty free waterways system that can promote interstate commerce was originated by the authors of The Federalist, according to Hull and Hull (1967), who also demonstrate how it influenced subsequent waterways policy and found its reflection in the Constitutions of several US states. Even WRDA'86, the act that substantially increased local participation for most water projects, postulates that the costs of construction for "inland waterway transportation" should be covered by the federal government (half of the costs derived from "the federal fund of the Treasury" and the other half from the "Inland Waterways Trust Fund").[9]

However, not all water projects were unanimously considered to create nationwide benefits. The interplay between national and local interests was often a centerpiece of the controversy surrounding water legislation.[10] The idea of adjusting cost sharing arrangements for water projects in accordance to the distribution of benefits was entertained decades before the passage of WRDA'86. The report of the Select Committee on National Water Resources, chaired by Robert S. Kerr of Oklahoma, reads:

> "With few exceptions, Federal work in the water resources field has been primarily in those areas where the benefits are widespread, or are intangible, so

[7] See Hull and Hull (1967) and Wahl (1989).

[8] See DelRossi and Inman (1998).

[9] WRDA'86, Sec. 102.

[10] See Wahl (1989) describing the history of federal irrigation subsidies. See also Maass (1951).

> that local interests are unwilling or unable to pay the costs. Strong justification can be presented also for some Federal work on water resources as an element of our national defenses. Ideally, **responsibility for bearing the costs should be divided**, between the Federal Government, with its funds derived from general tax revenues, and non-Federal interests, using funds put up by specific localities, **in proportion to the national and local benefits**. But the division point is not easy to determine..."[11]

The difficulty in determining the "division point" are twofold. First, benefits from a project are hard to estimate. Second, even given a good estimate of benefits the cost sharing should be chosen "just right". Too little federal assistance can leave room for a free-rider problem, mentioned in the above quotation: some projects generating positive externalities can be overlooked by sub-national (state) governments, even if deemed worthwhile on the national level. On the other hand, "too much" assistance can create the so called shared lunch problem: legislators will be motivated to choose excessively big and expensive projects as compared to those selected by a (fictitious) benevolent social planner. The latter type of inefficiency is often referred to as pork barrel spending, see Chari, Jones, and Marimon (1997) for the related analysis.

1.2. The Objective of the Paper

The WRDA'86 defines cost sharing arrangements for several types of water projects. The goal of this study is to evaluate these arrangements from the efficiency standpoint. More specifically, the question is whether the federal share of the cost was chosen in such a way as to avoid both the free-rider and the shared lunch problems discussed above.

Clearly, in order to give a meaningful answer to this question, one needs to get a reliable estimate of benefits both to the "local interests", or primary beneficiaries from the water projects that contributed to its cost, as well as the benefits to the rest of the regions. Instead of using the U.S. Army Corps of Engineers' (the Corps) estimates of benefits that were calculated **before** the project had been constructed, I will use the change in local market

[11] Report No. 29, 87th Congress, 1st session, reproduced from Hull and Hull (1967). (Emphasis added by A.R.P.)

indicators to elicit the benefits that accrued to the affected localities. The advantage of this approach is that it gives more precise estimates (just by the virtue of them being ex-post) and allows to access the benefits for each locality separately, instead of giving a total benefit estimate as that of the Corps. Nevertheless, this approach has several drawbacks. First, it can generate only the estimates of the benefits for the projects that were undertaken. Second and more important limitation is that it weakens the efficiency test that can be performed, due to the "selection bias". No longer is it possible to ask whether the chosen projects are "the best" feasible ones, rather, the test reduces to verification of whether the projects are "weakly" efficient or whether the benefit is bigger than the cost.[12] In other words the test is capable of detecting only the shared lunch problem. It does not verify whether any worthwhile projects were not undertaken, or, more generally, it is not an indicator of whether the transfer was "too small", thus ignoring the possible free rider problem.

This restriction is not extremely severe in the context of water projects, that were known to be prone to the shared lunch problem rather than the free rider one. Indeed, for several decades water legislation was associated with pork barrel politics. Ferejohn (1974) provides the detailed account of political process that governed the creation of water bills in the US prior to WRDA'86.

Summarizing the discussion, this paper is devoted to the following question: "Did new cost sharing rules introduced by WRDA'86 eliminate the pork barrel spending on water projects?"

1.3. Implementation

DelRossi and Inman (1998) analyze the "demand" for water projects before and after WRDA'86. They find that the size of a project chosen by a local representative is responsive to a change in cost sharing arrangements between federal and local government and that the

[12] This test is related to Inman and Fitts (1990) "constrained universalism" hypothesis stating that political process will produce the budget with total benefit (over all public projects) above the total costs. The difference is thata the test in this paper is aimed at comparing the benefits and costs on project by project basis.

spending was, indeed, reduced as a result. The estimated price elasticity of demand for water projects is strictly negative for all but small river channel projects. This responsiveness suggests that control over the local cost shares for water projects is an effective tool. Our aim is to suggest a way to check whether it is used efficiently.

In this paper I concentrate on a narrow class of public projects, namely, navigation and flood control projects, the cost sharing arrangements for which are non-trivial. In order to measure spillovers from the projects county level data before and after the construction will be used. The estimation of spillovers rests on two premises: mobility of the working population and perfect competition among firms. Given these assumption, the benefits from a project should be reflected in the local land rent and local wages. Clearly, according to the same hypothesis, a variety of other economic factors will be "capitalized" into these prices. Therefore to get a meaningful estimate of the benefits from water projects both in the region where the project was constructed and in the neighboring regions, it is necessary to control for changes in local and state government finances. Local changes are estimated on the basis of the Bureau of Census data from the late of 1970's and beginning of 1990's, while the state effects are eliminated by using the price variation in "control counties" belonging to the same state, but not affected by the project.

2. The Model

2.1. The Choice of a Water Project

Consider a country that is divided into S states and each state is divided into counties (regions). Let K be the set of all regions in the country. Every region is represented in the central legislature.[13]

[13] U. S. House representatives are elected by the residents of congressional districts, the boundaries of which rarely coincide with those of counties, but every county is included in a congressional district. If a water project was considered in a county that belongs to more than one congressional district, we will follow DelRossi and Inman (1998) in assuming that representatives of these districts share common objective of maximizing net benefit from a project for that county.

Assume the legislators know what water projects are feasible.[14] A feasible project i generates benefits across regions $(b_{ik})_{k\in K}$ and has cost C_i. The law specifies local cost share, ϕ_i, for project i.

Assume that legislator h knows the benefit accruing to his region from each one of the feasible projects as well as the corresponding local cost share and the total cost.[15] The legislator may decide to choose a project (possibly none) for his region out of the feasible set. Assume that he represents the interests of an average resident his district, h, so that his objective is to maximize the net benefit to region h, $b_{ih} - \phi_i C_i$. Thus he would like to include a project in the bill only if $b_{ih} \geq \phi_i C_i$.[16] There could be a project that, when constructed in region h, will substantially benefit its neighbors, whose representatives are willing to participate in its construction, even though the benefit to region h is not high enough to cover local costs. Indeed, there are several projects in our sample that have several counties listed as "local interests". In this case, I assume that the project is included, if the sum of all the benefits to all the local interests are above the non-federal cost share. The details of cost sharing between the affected regions is irrelevant for the following analysis.

The projects selected by all the representatives are then compiled into a bill that is subsequently authorized by Congress.

The utilitarian criterion implies that a project i should be constructed (authorized) iff $B_i \geq C_i$, where $B_i = \sum_{k\in K} b_{ik}$ denotes the total benefit from project i. Recall that by the

[14]In reality the set is determined by the Army Corps of Engineers who conduct feasibility studies, see DelRossi and Inman (1998) for details of the process.

[15]Any feasibility study conducted by the U.S. Army Corps of Engineers contains the division of the projects' costs into the federal and non-federal components. The cost sharing should comply with the federal law (see Regulation No. 1165-2-131 appendix F for details).

[16]Note that the legislator (the region he represents) can be "budget constrained". In the presence of a restriction on the amount of deficit/debt the local governments can run, the localities may have a restricted choice of the projects to choose from. The restriction may even prevent a locality from undertaking a project altogether. It could be interesting to investigate the effect of budget restrictions on projects choice, but it lies beyond the scope of this study. For our purposes note that the suggested specification allows for the budget restrictions to apply (that is why the statement contains just the "only if" part, presuming that if the local cost of a project is above local benefit the representative will not propose the project for construction). I would like to thank Prof. Jürgen von Hagen for this remark.

above assumptions a project is accepted if and only if

$$b_{ih} \geq \phi_i C_i, \tag{2.1}$$

which is equivalent to

$$\frac{b_{ih}}{C_i} \geq \phi_i. \tag{2.2}$$

Then, in case the local cost shares are set above local benefit shares,

$$\phi_i \geq \frac{b_{ih}}{B_i}, \tag{2.3}$$

one can be assured that only efficient projects will be accepted,

$$\frac{b_{ih}}{C_i} \geq \phi_i \geq \frac{b_{ih}}{B_i} \Rightarrow B_i \geq C_i. \tag{2.4}$$

The sufficient condition for efficient choice of projects 2.3 is the hypothesis that will be examined in this paper.

We will need the estimates of the benefits generated by the project to perform the examination. In order to do so consider a simple model of local economy. It is closely related to the framework developed in Gyorko and Tracy (1989) and in Haughwout and Inman (2001).

2.2. Local Economy and the Benefits from Water Projects

2.2.1. Maintained Assumptions

Each one of K localities has landowners, (resident) workers and firms. We will consider the firms in manufacturing, construction, transportation and public utilities as well as farming. Presumably, the profitability in these areas is directly affected by construction of water projects. Assume the following.

- The workers are mobile: they can move from county to county.

- Firms are perfectly competitive and mobile.

- Technology did not change in the relevant period $(1977-1992)$.
- Prices other than wages and rents changed over time in the same fashion across counties.
- The local economies return to an equilibrium after the construction of the water project.

2.2.2. The Local Economy

Homogeneous resident workers in locality h derive utility from a composite consumption good x_h^w, housing/land l_h^w, water projects G_h, as well as other public goods and local amenities affect workers well-being, a_h^w. They choose the quantity of the composite good and the land optimally given the price of the good q, rent P_h, wages W_h and taxes τ_h:

$$
\begin{aligned}
&\max_{x_h^w, l_h^w} U\left(x_h^w, l_h^w; \mathsf{G}_h, \mathsf{a}_h^w\right) \\
&s.t. \\
&q x_h^w + P_h l_h^w = \left(1-\tau_h\right) W_h
\end{aligned}
\tag{2.5}
$$

A worker supplies a unit of labor (leisure time is fixed).

Firms use technology that requires the use of capital k_h^f, land l_h^f, labor (number of employed workers) n_h^f, water projects G_h, as well as other public goods and local amenities that affect technology of production a_h^f. They produce the composite good taking the prices, interest rate i and taxes T_h as given:

$$
\max_{x_h^f, l_h^f, n_h^f, k_h^f} \left(1-T_h\right) \left[\begin{array}{c} q f\left(x_h^f, l_h^f, n_h^f, k_h^f; \mathsf{G}_h, \mathsf{a}_h^f\right) - \\ -P_h l_h^f \left(x_h^f, n_h^f, k_h^f; \mathsf{G}_h, \mathsf{a}_h^f\right) - \\ -W_h n_h^f \left(x_h^f, l_h^f, k_h^f; \mathsf{G}_h, \mathsf{a}_h^f\right) - \\ -i k_h^f \left(x_h^f, l_h^f, n_h^f; \mathsf{G}_h, \mathsf{a}_h^f\right) \end{array} \right], \tag{2.6}
$$

Land markets and labor markets clear in each locality h:

$$L_h = F_h l_h^f + N_h l_h^w; \tag{2.7}$$

$$N_h = n_h^f F_h, \tag{2.8}$$

where F_h is the number of firms in region h, N_h is the number of resident workers.

Global market for the composite good clears:

$$\sum_h x_h^f = \sum_h x_h^w \tag{2.9}$$

Neither firms, nor the workers do not want to move to another locality, as the indirect utility and the profits are equalized across regions:

$$V\left(W_h, P_h; \mathsf{G}_h, \mathsf{a}_h^w\right) = V_0, \tag{2.10}$$

$$\pi\left(W_h, P_h; \mathsf{G}_h, \mathsf{a}_h^f\right) = \pi_0. \tag{2.11}$$

Conditions $(2.5 - 2.11)$ along with a given ("world") interest rate i define an equilibrium $\left(P_h, W_h, N_h, n_h, k_h, F_h, x_h^w, x_h^f, l_h^w, l_h^f\right)$.[17]

Assume that the preferences and the technology adhere to the standard regularity assumptions that assure existence and uniqueness of equilibrium, see the remark below.

Remark. It is easy to see that once the solution (P_h, W_h) for the system of equations $(2.10, 2.11)$ exists and is unique (for each given h and for fixed V_0, π_0), the rest of the equilibrium can be easily found. For our purposes it is enough to have uniqueness in local prices (P_h, W_h) only. Existence of demand and supply for the composite good and land can be assured using standard concavity assumptions on utility and technology or by imposing weaker conditions as in Milgrom and Roberts (1994). To assure uniqueness

[17] The price of the composite good q, as well as the level of indirect utility V_0 and profits π_0 are indeterminate.

of local prices in equilibrium, it is enough to demonstrate strict monotonicity of the indirect utility and profit function in the prices. The latter can be shown using the envelope argument under the assumption that demands of the worker and demand for inputs of the firm are strictly positive. The last assumption is traditionally assured by imposing the "Inada" conditions on the utility and technology.

Graphical representation of the equilibrium in the space of local prices can help to develop the intuition for the measurement of benefits from public projects. See figure2.1.

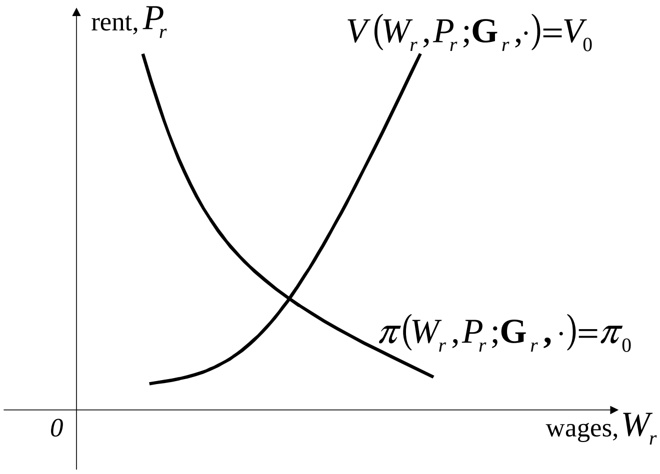

Figure 2.1: Local rents and wages in equlibrium.

Assuming the functions $(2.10, 2.11)$ are invertible and differentiable, one can solve the system to get the following (reduced) form:

$$W_h = w(\mathsf{G}_h; \mathsf{X}_h); \tag{2.12}$$

$$P_h = p(\mathsf{G}_h; \mathsf{X}_h), \tag{2.13}$$

where X is the vector of all the rest (exogenous) variables: $\mathsf{X} = \left(\mathsf{a}^w, \mathsf{a}^f\right)$.

Thus, both the wages and the rents should reflect the level of public good provision across localities, *ceteris paribus*. The way to elicit benefits from the project, or the willingness to pay is discussed in the next subsection.

2.3. The Benefits from Water Projects

Consider a project i that increases the size of public good, a dam, for example. Following a similar argument as in Gyorko and Tracy (1989),[18] one can claim that it is possible to infer the benefits generated by this change from the rents alone, i.e.,

$$b_{ih} = \frac{dp}{dG} = p_G.$$

The logic behind this claim is quite simple. The benefit from a public project is traditionally defined as the willingness to pay for it by the region. In terms of this model, it is the maximal amount that workers, firms and landowners in the region are ready to contribute for the project.

Assume first, that the dam only increases productivity and leaves the workers indifferent. If the firms' profits grow (above that in the neighboring regions), the land owners can increase the rent. This, in turn, makes the locality less attractive in the eyes of the workers, who can find better rent/wage combination elsewhere. Thus the wages have to increase in order to prevent the workers from leaving. Both prices continue to rise till the firms are left with the same profits as the neighboring ones (π_0) and the workers get their "reservation" utility V_0, the same as before the change. Therefore, after the equilibrium is restored, neither firms nor workers are ready to pay for the dam, as they do not benefit from its construction. The only beneficiaries in this model are the landowners, who absorb the increase in the rents.

Next, assume that, in addition, the workers enjoy the dam. Thus, they agree to pay higher rents or receive lower wages. Lower wages attract more firms who bid up the rents. Again, the change in rents "aggregates" the regional willingness to pay in this case.

[18] Similar statement appears also in Haughwout (2001).

The change in rents due to the change in the size of a public project can be expressed in terms of partial derivatives of the indirect utility and profit functions using the Implicit Function Theorem.[19]

$$p_G = \frac{\pi_G - \pi_W \left(\frac{V_G}{V_W}\right)}{-\pi_P + \pi_W \left(\frac{V_P}{V_W}\right)},$$

where the subscript refers to the variable with respect to which the partial derivative is taken. Coming back to the first case, if the workers do not directly enjoy the public good, so that $V_G = 0$, and the public project increases productivity, so that $\pi_G > 0$, the increase in rents should be positive. It will be dampened by the workers disutility of paying high rents, $V_P < 0$ and this effect will be smaller, the easier the workers are satisfied with the increased wages, as $V_W > 0$.

In the second case, when the workers like the project, so that $V_G > 0$, the rents will increase more, as $\pi_W < 0$.

Clearly, the above analysis is valid only if all the rest of the variables: other public goods and services, taxes, local amenities, etc. are constant. Therefore, it is necessary to control for the changes in these variables over time in order to properly estimate the benefits.

Furthermore, to simplify the estimation assume that the relationships $(2.12, 2.13)$ are affine. While not hoping to explain the data variation well, one can use this specification to approximate the first order effects of the water projects on rents and wages.

3. Estimation Methodology

3.1. Construction of the Data Sample

The initial sample consists of 19 navigation and 40 flood control projects authorized by WRDA'86. The counties in which the projects were constructed will be subsequently referred

[19] It is evident that one could employ Roy's identity to simplify this expression and present it in terms of demand functions. The advantage of the current approach, though, is that it does not require either estimating demand for public goods, or imposing any additional assumptions on the preferences in order to eliciting benefits from public projects using the demand functions.

to as “local interests”, following the U.S. Army Corps of Engineers terminology.

The data describing the projects, local cost shares and the project size, was borrowed from DelRossi and Inman (1998). The size of a project, Q, was calculated as its total annual cost (the Army Corps of Engineers estimate) deflated by city specific cost index determined by Haughwout and Inman (2001).

The “rent” used in this estimation is a composite index. One would expect that the water projects under consideration will affect residential, industrial as well as agricultural sectors. Therefore house values along with the farm values should affect decision making of an “average” firm. Denote by P the weighted sum of the house values and farm values, where the weights represent the percentage of non-farm and farm land correspondingly. The house values are approximated by the product of the median house value and the number of houses, while the farm value is approximated by the product of per-acre farm value and the land in farms. See equations $A.3, A.4$ in appendix $A.1$ for the precise definitions. Note that this specification allows for zoning barrier. The price is normalized by county land area in order to make meaningful comparisons across counties.[20] Let P_{ij}^b P_{ij}^a denote the price before and after the construction of the project i in county j correspondingly.

In order to account for all the relevant production activities, the wage will be constructed as a weighted average of wages in construction, manufacturing, transportation/public utilities, retail trade, wholesale trade and farming, where the weights are the proportion of employed in each sector. See equations $A.1, A.2$ in appendix $A.1$ for the precise definitions.

Decompose vector X into two parts: $\mathsf{X} = (\mathsf{Z}, \mathsf{Y})$ with the first part denoting local government finance variables, public projects and amenities, while the second part referring to the global variables (state and nationwide) of the same sort. See section 3.3 for the description of the variables constituting this vector.

Clearly, local amenities (climate, pollution, etc.) can affect both the utility of the workers and the productivity (or cost of production) of the firms. Therefore, they can also contribute to the differences in prices both across counties and over time. Let us divide the (omitted)

[20] Similar approach was adopted by Haughwout and Inman (2001).

local amenities into two groups: time invariant ones (climate, geographic location, etc.) and those that may vary across time (pollution, quality of health care, etc.). Let the first group compose the vector denoted μ and the second group - vector α.

3.1.1. Local Interests

Consider a county h, where project i is constructed. This county (or a group of counties) will be later referred to as "home county" or as "local interests". Let the county belong to state s_h. Then, before the construction the price and wage equations can be represented as

$$P_h^b = \mu_{ph} + \alpha_{ph}^a + \mathsf{Z}_h^b \delta_p + \mathsf{Y}_{s_h}^b \gamma_p + \varepsilon_{ph}^b \tag{3.1}$$

$$W_h^b = \mu_{wh} + \alpha_{wh}^b + \mathsf{Z}_h^b \delta_w + \mathsf{Y}_{s_h}^b \gamma_w + \varepsilon_{wh}^b \tag{3.2}$$

Remark. Note that the error terms, ε_{ph}^b and ε_{wh}^b can be correlated. This remark applies to all the systems of equations determining the prices (P, W) below.

After the construction, the prices should reflect the benefits generated by a project,

$$P_h^a = \mu_{ph} + \alpha_{ph}^a + G_i^f \beta_p^f + G_i^d \beta_p^d + \mathsf{Z}_h^a \delta_p + \mathsf{Y}_s^a \gamma_p + \varepsilon_{ph}^a \tag{3.3}$$

$$W_h^a = \mu_{wh} + \alpha_{wh}^a + G_i^f \beta_w^f + G_i^d \beta_w^d + \mathsf{Z}_h^a \delta_w + \mathsf{Y}_s^a \gamma_w + \varepsilon_{wh}^b, \tag{3.4}$$

where G_i is a vector characterizing the size of project i:

$$\begin{cases} G_i^d \equiv \left(Q_i^d, d_i Q_i^d\right), & \text{for a navigation project} \\ G_i^f \equiv \left(S_i Q_i^f, (1 - S_i) Q_i^f\right) & \text{for a flood control project} \end{cases},$$

where Q_i denotes the size of project i, it is strictly positive if the project was constructed in region h and zero otherwise; $S = 1$, if the flood control project was constructed on the Mississippi river and zero otherwise and d_i is the depth of the harbor resulted from a navigation project i. Project size data is from DelRossi and Inman (1998). It was calculated by the authors as total authorized spending deflated by the construction cost index.

For navigation projects the specification can be viewed as a linear approximation of a possible relationship with the first (Q_i) and second order $(Q_i d_i)$ terms, where depth is another proxy for the project size.[21] Similarly, Mississippi dummy S is supposed to differentiate "big" dams from smaller ones for flood control projects.[22]

3.1.2. Neighboring Counties

A project can generate externalities, affecting neighboring counties. For each county h, in which a project was constructed, we will pick a group of counties in the vicinity of h, $E(h)$. Let subscript n stand for the "neighboring" county.

Then the equilibrium conditions before the construction of project i for a neighboring county are identical to that in $(3.1, 3.2)$ with subscript h replaced by n. Clearly, the effect of a water project on neighboring counties may be different from its impact on the "local interest" counties. The following specification allows for this difference:

$$P_n^a = \mu_{pn} + \alpha_{pn}^a + G_i^f \theta_p^f + G_i^d \theta_p^d + \mathsf{Z}_n^a \delta_p + \mathsf{Y}_s^a \gamma_p + \varepsilon_{pn}^a, \quad (3.5)$$

$$W_n^a = \mu_{wn} + \alpha_{wn}^a + G_i^f \theta_w^f + G_i^d \theta_w^d + \mathsf{Z}_n^a \delta_w + \mathsf{Y}_s^a \gamma_w + \varepsilon_{wn}^a, \quad (3.6)$$

for each county n that has a common border (or a bridge) with locality h, in which project i was constructed. The choice of these neighboring (spillover) counties had to be somewhat restricted. None of the counties that constructed a water project of their own was chosen to be a "spillover county". Moreover, a county could be considered a spillover county for at most one project. Clearly, limiting the number of affected counties underestimates benefits from

[21] Besides, WRDA'86 uses depth of a harbor as a basis for cost sharing rules between federal and non-federal interests.

[22] It is important to bear in mind that this (reduced form) model is not powerful enough to disentangle effect of different water projects on the same region. Thus, if two projects, i and i' were constructed in the same region, we will estimate the effect of a "combined" project with size $Q_i + Q_{i'}$. There were 4 observations of this kind in a sample of 59 water projects. In order to avoid cumbersome notation, we will continue developing the estimation procedure under the assumption that no more than one project was constructed in a county.

a water project. On the other hand, some of the price variation in a county j neighboring to the one (h_0) with a project, but not included in its spillover calculation may be wrongly attributed either to its own water project or to the spillover from another project (if it belongs to the set of spillover counties for some other locality h_1 where a different project was constructed). In this sense benefits from water projects will be overstated. This introduces an additional "noise" in the estimates. This problem is relatively mild, though: only 3 or 4 projects in the sample can potentially be affected by it.

3.1.3. Control Counties

In order to eliminate state effects $(\mathsf{Y}_{s_\mathsf{h}}, \mathsf{Y}_{s_\mathsf{n}})$, we use control counties. State regulations, taxes, infrastructure, etc. and may affect relocation decisions of the firms and (probably, less so) of the workers. Clearly, it can translate into differences in land prices and wages. This effect should be neutralized for our purposes. For each county h in which project i is constructed, let us chose two control (unaffected) regions $k \in L(h)$, from the same state so that the following criteria are met (whenever possible):

1. the counties are not on the same major highway as county h;
2. the counties are not on the same waterway as county h ;
3. the counties are not on the same (obvious) real estate market as county h;
4. if h is rural, the control counties are rural, if h belongs to a big metropolitan area or contains big cities, so do the control counties;
5. the sizes of h and its control counties are compatible.

Denote county $k \neq h$ that belongs to the same state, but was unaffected by project i. Then, both before and after the construction of the project, $\tau \in \{a, b\}$ the equilibrium conditions imply

$$P_k^\tau = \mu_{pk} + \alpha_{pk}^\tau + \mathsf{Z}_k^\tau \delta_p + \mathsf{Y}_s^\tau \gamma_p + \varepsilon_{pk}^\tau \quad (3.7)$$

$$W_k^\tau = \mu_{wk} + \alpha_{wk}^\tau + \mathsf{Z}_k^\tau \delta_w + \mathsf{Y}_s^\tau \gamma_w + \varepsilon_{wk}^\tau \quad (3.8)$$

where the state (and federal) finances are the same as in (affected) region h, $\mathsf{Y}_s^\tau = \mathsf{Y}_s^\tau$. If a county n neighboring to a county h, where the projects was constructed, dose not belong to the same state as county h, (this is the case for some Mississippi dams, for example), then, clearly, the control counties had to be chosen in the same state as county n.

3.2. Difference in Difference Approach

3.2.1. Time differences

Taking differences over time eliminates μ, region specific effects that are invariable over time. Substracting the equilibrium conditions (term by term) before the construction from those after the construction generates the first difference equations for local interests,

$$\begin{aligned} \Delta P_h &= \Delta\alpha_{ph} + G_i^f \beta_p^f + G_i^d \beta_p^d + \Delta \mathsf{Z}_h \delta_p + \Delta \mathsf{Y}_s \gamma_p + \Delta\varepsilon_{ph} \\ \Delta W_h &= \Delta\alpha_{wh} + G_i^f \beta_w^f + G_i^d \beta_w^d + \Delta \mathsf{Z}_h \delta_w + \Delta \mathsf{Y}_s \gamma_w + \Delta\varepsilon_{wh}, \end{aligned}$$

for the spillover counties,

$$\begin{aligned} \Delta P_n &= \Delta\alpha_{pn} + G_i^f \theta_p^f + G_i^d \theta_p^d + \Delta \mathsf{Z}_n \delta_p + \Delta \mathsf{Y}_s \gamma_p + \Delta\varepsilon_{pn}, \\ \Delta W_n &= \Delta\alpha_{wn} + G_i^f \theta_w^f + G_i^d \theta_w^d + \Delta \mathsf{Z}_n \delta_w + \Delta \mathsf{Y}_s \gamma_w + \Delta\varepsilon_{wn}, \end{aligned}$$

and, finally, for control counties,

$$\Delta P_k = \Delta\alpha_{pk} + \Delta\mathsf{Z}_k\delta_p + \Delta\mathsf{Y}_s\gamma_p + \Delta\varepsilon_{pk}$$
$$\Delta W_k = \Delta\alpha_{wk} + \Delta\mathsf{Z}_k\delta_w + \Delta\mathsf{Y}_s\gamma_w + \Delta\varepsilon_{wk}.$$

3.2.2. Cross sectional differences

Next, taking the second difference will eliminate state specific public goods, taxes and regulations, Y_s.

Recall that each affected county (local interests and spillover counties) has a control county in the sample belonging to the same state. Thus an affected county and the its control county have identical state (and country specific) effects, Y_s. Hence, substracting the corresponding equilibrium conditions term by term eliminates these effects.

I will use the traditional notation for the second difference variables. For example, $\Delta\Delta P_h$ denotes $\Delta P_h - \Delta P_k$ and $\Delta\Delta P_n = \Delta P_n - \Delta P_k$.

In order to illustrate the relationships to be estimated I start with an example. Consider a county h in which a flood control project was constructed. Then the double difference in rents should be a function of the size of this project and local public finance variables,

$$\Delta\Delta P_h = c_p + G_i^f\beta_p^f + \Delta\Delta\mathsf{Z}_h\delta_p + u_{ph}, \tag{3.9}$$

$u = \Delta\Delta\varepsilon$, $c = \Delta\Delta\alpha$.

Recall that G^f is a vector. To clarify the following computations it is convenient to specify its elements, $QS, Q(1-S)$, where S is the Mississippi dummy. Then we get

$$\Delta\Delta P_h = c_p + Q_iS_i\beta_{1p}^f + Q_i(1-S_i)\beta_{2p}^f + \Delta\Delta\mathsf{Z}_h\delta_p + u_{ph}, \tag{3.10}$$

As for navigation projects $G^d = (Q, Qd)$, we get the following relationship for the double differences in rents:

Consider an affected county j. Then the second difference can be represented in the following manner

$$\Delta\Delta P_h = c_p + Q_i S_i \beta^f_{1p} + Q_i (1 - S_i) \beta^f_{2p} + \Delta\Delta \mathsf{Z}_h \delta_p + u_{ph}, \tag{3.11}$$

$$\Delta\Delta P_h = c_p + Q_i \beta^d_{1p} + Q_i d_i \beta^d_{2p} + \Delta\Delta \mathsf{Z}_h \delta_p + u_{ph}, \tag{3.12}$$

$$\Delta\Delta P_n = c_p + Q_i S_i \beta^f_{1p} + Q_i (1 - S_i) \beta^f_{2p} + \Delta\Delta \mathsf{Z}_n \delta_p + u_{pn}, \tag{3.13}$$

$$\Delta\Delta P_n = c_p + Q_i \theta^d_{1p} + Q_i d_i \theta^d_{2p} + \Delta\Delta \mathsf{Z}_n \delta_p + u_{pn}, \tag{3.14}$$

where $u = \Delta\Delta\varepsilon$, $c = \Delta\Delta\alpha$. The first pair of equations is aimed at estimating the effects of water projects in a "home" county, while the last two refer to the neighboring counties. Equations $3.11, 3.13$ are for the counties affected by a flood control project, while the rest, 3.12, 3.14 are for the navigation ones. Similarly, for the wages the system can be represented as

$$\Delta\Delta W_h = c_w + Q_i S_i \beta^f_{1w} + Q_i (1 - S_i) \beta^f_{2w} + \Delta\Delta \mathsf{Z}_h \delta_w + u_{wh}, \tag{3.15}$$

$$\Delta\Delta W_h = c_w + Q_i \beta^d_{1w} + Q_i d_i \beta^d_{2w} + \Delta\Delta \mathsf{Z}_h \delta_w + u_{wh}, \tag{3.16}$$

$$\Delta\Delta W_n = c_w + Q_i S_i \beta^f_{1w} + Q_i (1 - S_i) \beta^f_{2w} + \Delta\Delta \mathsf{Z}_n \delta_w + u_{wn}, \tag{3.17}$$

$$\Delta\Delta W_n = c_w + Q_i \theta^d_{1w} + Q_i d_i \theta^d_{2w} + \Delta\Delta \mathsf{Z}_n \delta_w + u_{wn}, \tag{3.18}$$

The results of estimation of the system $(3.11 - 3.18)$ is described in section 4.

3.3. Specification of Local Finances and Amenities, Z

The vector of local finances and amenities, Z, includes 12 variables.[23] Denote a typical element of this vector by $\left(z^k\right)^\tau$. For all the variables the time difference was taken over the 15 year period from 1977 ("before", $\tau = b$) till 1992 ("after",$\tau = a$). We will drop the time superscript for simplicity in the following description.

The first variable z^1 is property taxes per capita that typically enter budget constraint

[23] Source: USA Counties 1998, Version 3, Administrative and Customer Services Division, Bureau of the Census.

of a resident worker. As tax rates variation (over time and across counties) is very small, it will be natural to "amplify the change" in an attempt to detect its effect on the local prices. A natural way to do so is to look at tax revenues instead, which is chosen here.

Next, the quality of education z^3, may affect the residential choice of a worker. It is proxied by education expenditure per student enrolled in a local public school. In addition assume that both unemployment rate, z^{10}, and the crime rate, z^{11}, serious crimes known to police per $10,000$ residents, affect worker's utility. While unemployment rate may be an indicator of an expected job search time, crime rate would proxy an expected time that a worker can enjoy durable goods/savings.

In order to account for other local public goods, we include "other expenditures". They are calculated as a total direct general expenditures minus local government payroll as well as education and welfare spending. The result is supposed to capture "government investment" in the stock of "local amenities" that can be valued both by the resident workers and firm owners making production choices. This variable is in per capita terms. The impact of this spending, clearly, is different in the cities and in the rural areas. That is why we introduce two variables: expenditures in metropolitan areas, z^6, and expenditures in rural areas, z^5. The former one is the value of government expenditure deflated by the city specific cost index based on Haughwout and Inman (2001) multiplied by the "city dummy", an indicator of a metropolitan area. The latter is the expenditure times the indicator of a rural county. Besides, (z^8) the flow of intergovernmental transfers per capita (not including welfare transfers) can also enter decisions of firms and workers.

Clearly, firms' decisions are affected by a variety of local taxes. For the same reason before, we use tax revenues instead of tax rates. This approach has a drawback in the context of firms decisions, however. The resulting double difference is a combined indicator of both (possible) tax rate change and the change in the "economic activity", so it is not immediately clear what effect (on the prices) to expect. As our goal is not to identify the effect of taxes on rents and wages, but rather to eliminate it, we adopt this strategy. Total tax revenues per capita are denoted by z^2.

Production process is assumed to depend on the quality of infrastructure.[24] Thus, government spending on highways is included and denoted by z^4.

To proxy "local business conditions" I use the number of procurement contract awards by federal government to the region, z^7. It can be viewed as a flow of "local demand shocks". Another variable is the population density, z^9, that reflects both the size of potential market for the goods produced and a pool of potential employees.

In addition, both the firms productivity and workers' utility is assumed to be affected by the quality of the housing stock, z^{12}. Presumably, the newer are the houses, the better is the quality. Therefore, controlling for the proportion of old houses (built before 1939) can be viewed as an indicator of deterioration of the housing. Clearly, the same house in 1980 has better quality than in 1990. I have used the depreciation rate of 5.6% estimated in Greenwood, Hercowitz, and Krusell (1997) for structures to account for this effect.

4. Results

First, using the sample of local interest counties and their neighbors, I estimated the following system using three stage least squares (3SLS):

$$\Delta\Delta P_j = c_{pj} + t_h\left(G_i^f\beta_p^f + G_i^d\beta_p^d\right) + t_n\left(G_i^f\theta_p^f + G_i^d\theta_p^d\right) + \Delta\Delta \mathsf{Z}_j\delta_p + u_{pj}, \qquad (4.1)$$

$$\Delta\Delta W_j = c_{wj} + t_h\left(G_i^f\beta_w^f + G_i^d\beta_w^d\right) + t_n\left(G_i^f\theta_w^f + G_i^d\theta_w^d\right) + \Delta\Delta \mathsf{Z}_j\delta_w + u_{wj}, \qquad (4.2)$$

where the subscript j refers to the county, t_h is a dummy for a "home" (local interest) county, t_n is a dummy for a neighboring county. Given that the sample consists only of the counties of these two types, $t_h = 1 - t_n$. Therefore only one of the bracketed terms is strictly positive for a given county. Moreover, typically only one type of project (navigation or flood control) was constructed in a county, thus one term inside the brackets is zero.

[24]See Haughwout and Inman (2001) for a possible specification of technological process that involves government investment in infrastructure.

Clearly the system $4.1 - 4.2$ is equivalent to $3.12 - 3.17$.

The results of the estimation are presented in appendix B.

4.1. Discussion of the Equilibrium Estimation Results

This discussion be focused on the effect of the water projects on the prices. It is interesting to analyze the impact of the other variables as well, but it lies beyond the scope of this paper.

First, notice that the “first order” effect of the navigation projects (coefficient of the size) on the rents is positive and insignificant on the wages. This pattern is consistent with an increase in firms profits (the same profits are attainable at higher (W, R) combinations) and in workers' utility (the same level of indirect utility can be attained for higher R and lower W combinations). This is true for both the local interests and the spillover counties, only the effect on a spillover county's rents is smaller.

Moreover, observe that the marginal “second order effect” (interplay of project size and the depth of the harbor) is negative. It is tempting to use this observation to suggest a rationale behind the structure of cost sharing for navigation projects in WRDA'86. According to this law, local participation should be an increasing function of the “depth” of the project: for deep draft projects 50% of the cost is to be covered by non-federal interests. If the depth is intermediate (20 up to 45 feet), required local participation drops to 25%, and it is 10% for the harbors shallower than 20 feet.[25] Given these rules and taking the estimates seriously, a locality (or its representative) could decrease the depth keeping the size of the project constant and end up with both higher benefits and lower local costs. In this case the change will be in the interest of the utilitarian social planner, provided the total cost of the project stayed the same (or decreased) as a result. In addition to that though, a locality will be willing to trade-off the depth of the harbor for its size, as the “first order” effect of

[25] In practice, the cost shares vary due to a variety of technological and administrative reasons (see Army Corps of Engineers documentation). The trend is preserved, however, deeper harbors are financed more heavily by local governments.

increase in size is significantly bigger than the "second order" detrimental effect that can further be reduced by the decreased depth. Whether or not this choice is socially optimal depends on the technology of construction. Thus, although true that the law discourages deep draft projects, it is not immediately evident that the rule has the efficiency rationale based on the estimation results. Besides, the harbor depth may be historically/geographically predetermined and, therefore, not be a choice variable for the politicians.

As for the flood control projects, the statistically significant estimate of the effect of a non-Mississippi project on wages in spillover county is negative. This is consistent with a positive impact on the welfare of local residents, who are willing to trade off their wages for a smaller risk of a flood. The effect on firms profits is unclear, however. At this point it possible to speculate that a dam may change irrigation patterns in the county, so that some of the upstream farms will benefit while the downstream farms may incur losses. Thus, the "average" effect can be questionable.

Presumably, a more specific model that takes into account changes in the farm production due to the construction of a flood control project can shed light on a more precise way to elicit the benefits it brings.

4.2. Examining the Hypothesis

4.2.1. Calculation of Benefits Ratios

Recall that rents were measured in per acre terms. Thus, for example, $Q_i\beta^f_{1p}$ measures the benefits from of a (Mississippi) flood control project per acre in locality h. To get the total benefit for this locality, then, the effect should be multiplied by its land area in acres, A_h,

$$\hat{b}_{ih} = A_h Q_i \hat{\beta}^f_{1p}. \tag{4.3}$$

In general, the estimated local (direct) benefit that accrued to county h is computed as follows:

$$\hat{b}_{ih} = \begin{cases} A_h Q_i \hat{\beta}^f_{1p} & \text{Mississippi projects} \\ A_h Q_i \hat{\beta}^f_{2p} & \text{non-Mississippi flood control projects} \\ A_h \left(Q_i \hat{\beta}^d_{1p} + Q_i d_i \hat{\beta}^d_{2p} \right) & \text{navigation projects} \end{cases} \tag{4.4}$$

If the project was shared by several counties, then the direct benefit is the sum over all the benefits that accrued to all of these counties.

As for neighboring county n, the calculation is similar,

$$\hat{b}_{in} = \begin{cases} A_n Q_i \hat{\theta}^f_{1p} & \text{Mississippi projects} \\ A_n Q^f_i \hat{\theta}^f_{2p} & \text{non-Mississippi flood control projects} \\ A_n \left(Q_i \hat{\theta}^d_{1p} + Q_i d_i \hat{\theta}^d_{2p} \right) & \text{navigation projects} \end{cases} \tag{4.5}$$

For each "home" county h the set of its neighbors will be denoted by $E(h)$. Let the estimated spillovers, $\hat{b}_{iE(h)}$, be defined as follows:

$$\hat{b}_{iE(h)} = \sum_{n \in E(h)} \hat{b}_{in} \tag{4.6}$$

Then, the estimated benefit ratio is

$$\hat{\kappa}_i = \frac{\hat{b}_{ih}}{\hat{b}_{ih} + \hat{b}_{iE(h)}}. \tag{4.7}$$

Given the estimates 4.7 it is now possible to check the hypothesis (2.3).

Notice that although the impact of some water projects on the prices may be statistically insignificant, the estimate of the ratio of the benefits can still have a relatively small variance and, thus a "tight" confidence interval and vice versa.

4.2.2. Estimation for Navigation Projects.

By (4.7) the estimated benefits ratio is

$$\hat{\kappa}_i = \frac{A_h\left(Q_i\hat{\beta}^d_{1p} + Q_i d_i \hat{\beta}^d_{2p}\right)}{A_h\left(Q_i\hat{\beta}^d_{1p} + Q_i d_i \hat{\beta}^d_{2p}\right) + \sum_{n\in E(h)} A_n\left(Q_i\hat{\theta}^d_{1p} + Q_i d_i \hat{\theta}^d_{2p}\right)}$$

The results of this computation are summarized in the figure 4.1 that includes benefit ratios for the projects with positive total benefit. The estimates for benefit ratios for navigation projects are plotted against the corresponding local cost shares. The estimates that fall below the diagonal line correspond to the projects with local cost share above the benefit ratio in accordance with the weak efficiency criterion, 2.3.

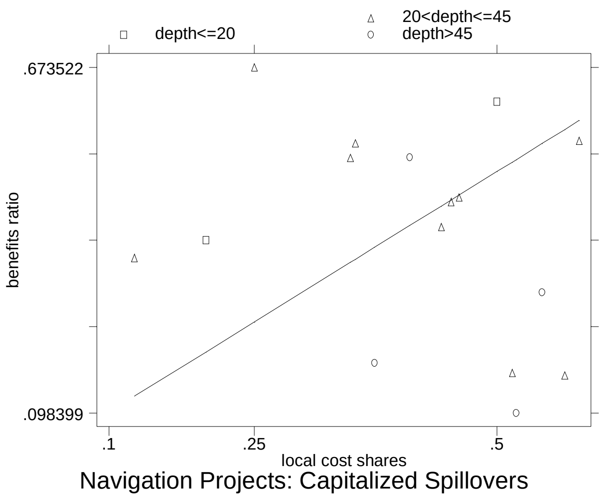

Figure 4.1: Estimated benefit ratios and the corresponding local cost shares.

How precise are these estimates? To approximate the (95%) confidence intervals around the estimates, I used the Delta method.[26] The resulting intervals appear to be quite small,

[26]This method is based on an approximation. The variance of a function $f\left(\hat{\beta},\hat{\theta}\right) = \kappa$ of the estimated parameters is calculated as a quadratic form, $G\hat{V}G^T$, where $\hat{V}$ is the estimated variance of the parameters and $G = 0_{(\beta,\theta)} f\left(\hat{\beta},\hat{\theta}\right)$ is the first derivative of the function with respect to the parameters. See Greene (1993), page 297 for details.

as the table in appendix B indicates. The confidence intervals were calculated based on robust estimates of the variance.[27]

Why do come cost shares fall satisfy the efficiency criterion, while the others fall into the "grey zone" (above the diagonal)? Could political factors have influenced the "cushy" cost sharing arrangements? A thorough investigation could be an interesting avenue for future research. As a preliminary step, one could observe that all the projects that have estimated benefit ratios above the local cost shares had a representative in the Senate Water Committee, while not all of the rest did. This is not true for the House Water Committee membership, though.

4.2.3. Flood Control

As for the flood projects, calculation of the benefit shares did not bring fruitful results. Few projects have positive estimated total benefit. One of the possible explanations for this result is that the impact of these projects may be "very local", accruing to small communities (groups of households and farms), thus, on the county level the effect may be negligible. Moreover, the construction of a dam, for example can improve irrigation on some upstream farms and deteriorate the conditions for the downstream ones. On the aggregate level these opposite effects may cancel each other. Therefore this level of aggregation may be inappropriately high for detecting the effects of these projects. Lower level analysis with a more detailed description of farm technology and flood hazards could produce more promising results. This is left for the future research.

[27] The 3SLS estimation of the reduced system of the price equations (4.1, 4.2) is identical to estimating the seemingly unrelated regressions system using GLS (Zellner (1962), Zellner and Theil (1962)). The latter method produces (algebraically) identical results to equation by equation OLS when the explanatory variables for both equations are the same (see Davidson and Mackinnon (1993)). I have performed both calculations to check the severity of possible numerical problems, which appeared to be negligible. The benefit ratio estimates and their confidence intervals were calculated based on the OLS estimation of the rents equation allowing for spatial correlation (clustered by the project number).

5. Conclusions

In this model I used a modification of a standard capitalization hypothesis to estimate benefits from public projects in order to evaluate efficiency rationale behind WRDA'86. According to the estimates pork barrel spending for the navigation projects was reduced. Estimated benefits shares for some navigation projects are below the local cost shares, which is in accordance with the weak efficiency criterion developed in the paper

This approach is much less restrictive than usual cost benefit analysis, that require explicit evaluation of demand for public goods.[28] An indirect estimates for the benefits generated by public goods enabled to avoid usual assumptions on behavior that are traditionally made to use that evaluation. It also departs from "classical" capitalization postulate assuming that the benefits from public goods as well as the value of taxes will be incorporated exclusively in the house/land values, ignoring possible interactions with the wages.[29] Following a more recent trend in the literature, we allow for mobility of working population. One of the first contributions in this respect is Rosen (1979), suggesting that wages across localities should reflect differences in public goods/amenities. The model used in this paper is a simple version of the one analyzed in Haughwout, Inman, Craig, and Luce (2000). Note, however, that an important assumption underlying the model that was used in this paper was that the workers do not own land. Relaxing this assumption can generate a different prediction about the response of wages to the construction of public projects, but the house prices can still be interpreted as reflecting benefits generated the projects.

In addition to the main result, the estimation of the simple linear model of spatial equilibrium confirms the prediction that navigation projects can be viewed as government investment that boosts profitability of the firms.

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[28] See Mishan (1976), Drèze and Stern (1987) for the fundamental treatment of cost-benefit analysis. This approach is being mainly used to evaluate future projects rather than to analyze the consequences of those already constructed.

[29] Lind (1973) introduces the capitalization idea in an elegant framework of optimal (tasks to parcels) assignment problem.

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A. The Data

A.1. Definitions of the variables

The definition of wages is based on the data issued by the Bureau of Economic Analysis[30] The rest of the variables are constructed from the Bureau of the Census data,[31] and is based on its codes. All monetary variables were translated into 1992 dollar values using the CPI index. To simplify notation region specific subscript will be omitted.

A.1.1. Wages (DWe)

$$W^a = \frac{CTe92 + MFe92 + RTe92 + TPe92 + WSTe92}{CTm92 + MFm92 + RTm92 + TPm92 + WSTm92} \tag{A.1}$$

$$W^b = \frac{CTe80 + MFe80 + RTe80 + TPe80 + WSTe80}{CTm80 + MFm80 + RTm80 + TPm80 + WSTm80} \tag{A.2}$$

$$DWe = W^a - W^b$$

where $CTe92$, $MFe92$, $RTe92$, $TPe92$, $WSTe92$ are **total** yearly earnings ($) in construction, manufacturing, retail trade, transportation/public utilities and wholesale trade cor-

[30]Source: U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, Regional Economic Measurement Division, Regional Economics Information System, CD-ROM 1969-1997 v. 3.0.0.

[31]Source: USA Counties 1998, Version 3, Administrative and Customer Services Division, Bureau of the Census

respondingly. The last two digits in the variable name correspond to the calendar year of the estimate. Similarly, $CTm92$, $MFm92$, $RTm92$, $TPm92$, $WSTm92$ denote number employed in the corresponding sectors.

A.1.2. Rents (Dhv)

$$P^a = \frac{(100 - ag33092) * hs22090 * hs20090 + ag33092 * ag44092 * ag32092}{100 * 640 * ln03090} \tag{A.3}$$

$$P^b = \frac{(100 - ag33082) * hs22080 * hs20080 + ag33082 * ag44082 * ag32082}{100 * 640 * ln03080}, \tag{A.4}$$

where the variables are described by the following table. In this definition $ag330xx$ is the land in farms as a percent of total land in year xx, $ag440xx$ is the average value of land and buildings per acre in year xx, $ag320xx$ is the land in farms in acres, year xx, $hs200xx$ is the number of owner-occupied housing units 1980 (100%) in year xx, $hs220xx$ is the median value of specified owner-occupied noncondominium housing units 1980 (100%) in xx, $ln030xx$ is the land area in square miles in xx.

A.1.3. Local Finances and Amenities

Property tax revenues per capita ($Dprtcp$)

$$\Delta z^1 = gl66092 - gl66077,$$

where $gl660xx$ stands for local government finances - general revenue, property taxes per capita FY 19xx.

Total local tax revenues per capita ($Dtax$) Define this indicator for region h as follows:

$$\Delta \left(z^2\right)_h = \frac{(gl64092)_h}{(po01192)_h} - \frac{(gl64077)_h}{(po01077)_h},$$

where $gl640xx$ stands for local government finances - general revenue, total taxes FY 19xx; and $po01yxx$ is for resident population (July 1) 19xx.

Education Spending per Enrolled Student ($Deduc$)

$$\Delta\left(z^3\right)_h = \frac{(gl70092)_h}{(ed24092)_h} - \frac{(gl70077)_h}{(ed24079)_h}, \tag{A.5}$$

where $gl700xx$ stands for local government finances direct general expenditures for education FY 1977; and $ed240xx$ is Public school enrollment Fall $(19xx - 1)$

Highways Spending ($Dhighw$) Define the change in this stock variable as follows.

$$\Delta z^4 = gl73092 + gl73087 + gl73082 + gl73077,$$

where $gl730xx$ is the spending on highways in xx.

Other expenditure ($Dexp$) Recall, this variable is a proxy for government "investment". To measure the change in the stock of public amenities, we have to sum over the flow of investment over the period. We take the average flow as explanatory variable. Define

$$U^{92} = gl68092 - gl70092 - gl72092 - gl82092 - gl73092,$$

and let U^{87}, U^{82}, U^{77} in the similar manner. Calculate

$$\Delta U = \frac{1}{4 * (po01192)_h}\left(U_h^{92} + U_h^{87} + U + U_h^{77}\right)$$

The key for the variables used in this calculation follows: $gl680xx$ are the local government finances - direct general expenditures, total FY $19xx$, $gl700xx$ are the local government finances - direct general expenditures for education FY $19xx$, $gl720xx$ are the local government finances - direct general expenditures for public welfare FY $19xx$, $gl820xx$ is the local government payroll (October) $19xx$, $po01192$ is the resident population in $(July\ 1)\,1992$.

Define also the $RURAL$ dummy: $RURAL = 1$ for counties that do not belong to any metropolitan area.

Finally, define

$$\Delta z^5 = (Dexp) = RURAL * \Delta U;$$
$$\Delta z^6 = (Dexpcityr) = (1 - RURAL) * \Delta U_h / p_h,$$

where p_h is the Haughwout-Inman city specific cost index for region h.

Procurement Contract Awards $(Dpcont)$ These federal contracts are viewed here as a flow of demand shocks. Again, in order to measure the total shock, we have to accumulate the flow over the period and average for convenience. Define

$$\Delta z^7 = \frac{1}{10} \sum_{\tau=83}^{91} gf060\tau \tag{A.6}$$

In this calculation $gf060xx$ stands for direct federal expenditures or obligations - procurement contract awards, total FY 19xx.

Intergovernmental Transfers per capita $(Digr)$ The transfers are treated as a flow:

$$\Delta z^8 = \frac{1}{4 * (po01192)_h} \sum_{\tau \in \{92,87,82,77\}} (gl620\tau - gl720\tau)_h \,,$$

where $gl620\tau$ are referred to as local government finances - general revenue, intergovernmental FY 19τ, $gl720\tau$ stand for local expenditure on welfare, as before.

Population Density $(Dpconc)$ Define population in locality j density as an indicator:

$$\Delta z^9 = (po01190)_j \,/\, (ln03090)_j - (po01080)_j \,/\, (ln03080)_j \,.$$

Unemployment rate $(Dunem)$ Unemployment rate is an indicator as well:

$$\Delta z^{10} = lb05092 - lb05077,$$

where $lb050$ stands for civilian labor force unemployment rate $19xx$.

Crime Rate ($Dcrime$) Define yet another indicator,

$$\Delta z^{11} = ch02092 - ch02077,$$

where $ch020xx$ is the number of serious crimes known to police (crime index) $19xx$.

Old housing ($Dold$) The last indicator for region h is defined as follows:

$$\Delta \left(z^{12}\right)_h = \frac{(0.994)^{10} (hs45890)_h}{(hs02090)_h} - \frac{(hs55680)_h}{(hs02080)_h},$$

where $hs45890, hs55680$ are housing units by year structure built in 1939 and before, 1990 and 1980 correspondingly, while $hs020xx$ is the total number of housing units in $19xx$.

B. Estimation Tables

Table B.1: 3SLS Estimation of the Price Variation

	DDhv	t	DDWe	t
QFCh	0.0242038	0.97	-0.0038437	-1.14
QFCmh	-0.4011093	-1.29	-0.0237433	-0.57
QFCn	-0.0189562	-1.31	-0.006845	-3.5
QFCmn	-0.0066537	-0.04	0.0177194	0.81
QNh	1.353456	7.35	-0.0132819	-0.53
QNDh	-0.0258995	-7.18	0.0002882	0.59
QNn	0.5082807	4.89	0.0166053	1.18
QNDn	-0.0095185	-4.68	-0.0002541	-0.93
DDprtcp	14.77504	0.47	2.124132	0.5
DDtax	-9020.217	-0.31	4707.305	1.21
DDeduc	-51.95136	-0.03	-63.3485	-0.3
DDhighw	0.0361797	3.68	0.0019013	1.43
DDexp	-2.06E-07	-0.22	-8.98E-08	-0.7
DDexpcityr	2.30E-07	1.85	1.77E-08	1.05
DDpcont	0.0078599	2.98	0.0011761	3.3
DDigr	-6.62E-09	-3.77	-5.56E-10	-2.35
DDpconc	16.96939	1.5	2.802894	1.84
DDunem	-394.8918	-0.59	64.59885	0.71
DDcrime	0.9417865	1.11	-0.1082322	-0.94
DDold	-53322.39	-2.12	-11302.11	-3.33
constant	1714.534	0.84	283.7403	1.03

Equation	Obs	Parms	R^2	χ^2
first ($\Delta\Delta P$)	239	19	0.4252	169.03
second ($\Delta\Delta W$)	239	19	0.2601	83.65

The first four variables correspond to the flood control projects: $QFCh = Q^f(1-S)*t_h$; $QFCmh = Q^f S*t_h$; $QFCmn = Q^f S*t_n$; $QFCn = Q^f(1-S)*(1-t_h)$; while the subsequent four are for the navigation: $QNh = Q^d * t_h$ $QNn = Q^d * t_n$; $QNDh = Q^d d * t_h$; $QNDn = Q^d d*t_n$,where t_h is a dummy for the local interests, t_n is a dummy for a neighboring county, S is a dummy for a Mississippi project.

Table B.2: Confidence Intervals for the Estimated Benefit Ratios for Navigation Projects

lower boundary	estimated benefits ratio	lower boundary
0.29883795	0.29883889	0.29883983
0.35613195	0.35613279	0.35613362
0.16516647	0.16516662	0.16516677
0.55082649	0.55082679	0.5508271
0.09839802	0.09839949	0.09840096
0.44958809	0.44959048	0.44959288
0.16054163	0.16054248	0.16054334
0.67352097	0.673522	0.67352304
0.523653	0.52365343	0.52365386
0.61640234	0.61640731	0.61641228
0.52251746	0.52252036	0.52252326
0.45714739	0.45714814	0.4571489
0.18166756	0.18166825	0.18166893
0.38608671	0.38609154	0.38609637
0.40739638	0.40739729	0.40739821
0.42816349	0.42816457	0.42816565
0.54654669	0.54654747	0.54654824

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