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Are Public Investment Efficient in Creating Capital Stocks in Developing Countries?

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Abstract

In many poor countries, the problem is not that governments do not invest, but that these investments do not create productive capital. So, the cost of public investments does not correspond to the value of the capital stocks. In this paper, we propose an original non parametric approach to evaluate the efficiency function that links variations (net of depreciation) of stocks to public investments. We consider four sectors (electricity, telecommunications, roads and railways) of two Latin American countries (Mexico and Colombia). We show that there is a large discrepancy between the amount of investments and the value of increases in stocks.

1 Introduction

Since the seminal works of Aschauer (1989), the measure of the productivity and the efficiency of infrastructure and public capital has been the subject of many empirical studies, for OECD countries (see the surveys of Gramlich, 1994 or Sturm, 1998) but also for developing countries (World Development Report for 1994, Canning, 1999, or Easterly and Serven, 2004). The traditional method used to estimate capital stocks for OECD countries is the Perpetual Inventory Method (PIM, thereafter). This well known method consists in cumulating historical series of past investments and in deducting assets which were retired. The PIM has been used to estimate public capital stocks among others by Sturm and De Haan (1995) for the Netherlands,Berndt and Hansson (1992) for Sweden, Ford and Poret (1991) for France and Japan and more recently by Kamps (2004) for as sample of 22 OECD countries. But Pritchett (1996) showed that in many poor countries the problem is not that governments do not invest, but that these investments do not create productive capital. The cost of public investments does not correspond to the value of the capital stocks. Pritchett estimates that only slightly more than half of the money invested in investment projects will have a positive impact on public capital stocks in developing countries.

Consequently, we propose to evaluate the relationship between the increase in monetary value of stocks and the current monetary value of public investments in two developing countries, Colombia and Mexico. This relation, called efficiency function, indicates the value of the public capital produced by one dollar's worth of government investment spending. If the PIM is valid, we should verify that one invested dollar increases the stock value with one dollar. On the contrary, if it is observed that the stocks value is increased with less than one dollar, it implies that the PIM overvalues the public stocks. Using infrastructure physical measures proposed by Canning (1998), we adopt a non-parametric approach to give an estimate of the portion of public investments that are efficient in creating capital.

The rest of the paper is organized as follows. Section 2 is devoted to the measure of public investment efficiency. Section 3 presents tthe results and section 4 concludes.

2 Public Investment Efficiency : Data and Methodology

Pritchett (1996) and Canning (1998) state that the same investment flows in different countries may have very different effectiveness in actually producing capital, due to the differences in public sector efficiency and differences in the price of capital. If the investment project is carried out by public sector, actual and economic costs (defined as the minimum of possible costs given available

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technology) may deviate. So, the use of monetary investment may introduce systematic errors in the amount of public capital actually produced.

Let us consider the following capital accumulation relationship:

$$K_{t+1} = (1 - \delta) K_t + f(I_t) \tag{1}$$

where K_t denotes the public capital stock at time t and I denotes the corresponding gross public investment. The function $f(I_t)$, called efficiency function, represents the efficiency of public investments to generate new capital. If we assume that only a certain part of investments is used to create capital, the function $f(.)$ may differ from identity function. We only know that it satisfies the following constraints:

$$0 \leq f(I_t) \leq I_t \tag{2}$$

$$f(0) = 0 \tag{3}$$

The fact that $f(I_t)$ can be strictly inferior to I_t reflects the inefficiency of public investments in creating capital. Since no natural specification of the efficiency function $f(.)$ can be justified *a priori*, a solution consists in estimating this function by a non parametric method for a typical developing country or for a sub-group of developing countries. For this purpose, three inputs are required: (1) a series of public investments (2) the depreciation rates (or its time profile) and (3) a series of public capital stocks effectively available in the reference countries. The first and the second element are available in the literature (World Bank, Bureau of Economic Analysis) for many countries. But the last element does not exist. Consequently, in this study, we propose to estimate the efficiency function by using physical measure of infrastructure as a proxy of public capital stock effectively available in developing countries. To the best of our knowledge, only the Calderon, Easterly and Serven's database (2004) about nine countries of the Latin America[1] give an enough detailed decomposition of the public investments for a long period of time (1980-1998) that allows us to establish a correspondence with the physical measures proposed in the Canning's database (1998) from 1950 to 1995. That is why we choose two reference Latin American countries, Colombia and Mexico. For these two countries we compare past investments flows given by Calderon et al. (2004) to physical measure of infrastructure stocks given by Canning (1998) over the period 1981-1995 in four sectors: Electricity, Telecommunication, Roads, and Railways.

The first problem of this approach is that it considers sectors for which private investments may be important. As in most of Latin America countries, the proportion of private versus public investments in infrastructure deeply changed during the period 1980-1995 in these two reference countries. So, we consider only a period for which the part of private investments in total investments is not important. More precisely, for each sector, the sample used for estimation starts

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[1] Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela.

in 1981. The ending dates[2] have been chosen such that during the considered period of time, the amount of the private investments in the total investments of the specified sectors never exceeds 15%. Generally, these dates correspond to the reform dates pointed out by Calderon, Easterly and Serven (2004).

The second problem is the correspondence between investments categories and the infrastructure physical measures proposed by Canning (1998). To measure infrastructure in the electricity sector we consider electricity-generating capacity expressed in million of kilowatts. For the telecommunication sector, we use the number of telephone main lines. Two measures are possible for the roads sector: the number of road kilometers or the number of paved road kilometers. We decide to use the measure that offers the maximum of available observations. Thus, for Mexico we use the number of road kilometers while for Colombia we use the number of paved road kilometers. Finally, to measure investments in the railways sector, the length of the railway system (in kilometers) is used.

Given these sectoral data, how to estimate the functional form of the public investment efficiency function? This function relates on the one hand monetary flows of investments expressed in million US dollars and on the other hand public capital stocks measured in the same monetary unit. However, we have only physical measures of these stocks. Our methodology is then the following. Let us assume that, for a sector $j = 1, .., 4$, the capital stocks (expressed in monetary units) can be defined as follows:

$$K_{jt} = v_{jt} X_{jt} \tag{4}$$

where X_{jt} denotes the physical measure of the capital in the sector j and v_{jt} represents the monetary value of one physical unit of capital.

We assume that the efficiency function of public investments is specific to each sector: $f_j(.)$ denotes the efficiency function associated to the jth sector. Our objective is to estimate the function $f_j(.)$ defined as:

$$K_{j,t+1} - (1 - \delta_j) K_{jt} = f_j \left(\beta_{jt} I_{jt} \right) \tag{5}$$

where I_{jt} denotes public investments in the sector j and β_{jt}, with $0 \leq \beta_{jt} \leq 1$, denotes the part of these sectorial investments which actually correspond to the assets considered in the Canning's database. For instance, if we consider the electricity sector, we can state that a part of public investments in this sector is allocated for something else than the increase of electricity generating capacity (security investments, investments made to preserve the natural environment for instance). This part of public investments does not correspond to unproductive investments. The parameters β_j only measures the inadequacy between our

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[2]For the case of Columbia, the ending dates are: 1993 for the electricity sector, 1994 for telecom and roads sectors. Data concerning public investments for the railways sector are not available. For the Mexico, the dates are: 1998 for the electricity sector, 1990 for the roads and 1989 for the railway sector. The data concerning the road infrastructures before the reform (1989) are not available.

sectorial decomposition of investments and the physical asset considered in the Canning database.

For the four reference sectors, we calculate the depreciation rate δ_j using the BEA (Bureau of Economic Analysis, 2003) depreciations rates. For each type of investment two depreciation rates are proposed by the BEA: one for equipment and one for structures. The only exceptions are the investments in roads for which only structure assets are reported. Taking into account these information, we compute a weighted average of the rates on structures and equipment for the four components of public investments used. The weights are defined by the average part of equipment assets (respectively structure assets) in the total government net stocks of the United States over the period 1950-1996. The weights used are then equal to 83.17% for structures and to 16.83% for equipment. The corresponding depreciation rates for the four components of public investments are reported in Table I.

If the function $f_j(.)$ is homogenous of degree λ, equation (5) can be expressed as relationship between the physical measures of infrastructure X_{jt} and the monetary investments I_{jt} as:

$$\widetilde{v}_{j,t+1}X_{j,t+1} - (1 - \delta_j)\,\widetilde{v}_{j,t}X_{j,t} = f_j(I_{jt}) \tag{6}$$

with $\widetilde{v}_{j,t} = v_{j,t}/\beta_{jt}^{\lambda}$. In this expression, except the function $f_j(.)$, only the valuations $v_{j,t}$ and the proportions β_j are unknown. In order to evaluate them, we propose to compute a sequence of values of $\widetilde{v}_{j,t}$ in order to get a situation as close as possible to the full efficiency situation, that is to the PIM for which one invested dollar increases the capital of exactly one dollar. More precisely, we know that, if PIM is valid, the sequence $\widetilde{v}_{j,t}$ is defined by the recurence equation:

$$\widetilde{v}_{j,t+1}X_{j,t+1} - (1 - \delta_j)\,\widetilde{v}_{j,t}X_{j,t} = I_{jt} \tag{7}$$

Let us assume that $\widetilde{v}_{j,t}$ has a geometric evolution:

$$\widetilde{v}_{j,t} = v\,(1 + \gamma)^t \tag{8}$$

This assumption allows us to take into account the inflation of the costs associated to the construction of one physical infrastructure unit. The problem only consist in determining parameters (v, γ), which (conditionally to X_{jt} and I_{jt}) give us the valuation dynamics $\widetilde{v}_{j,t}$ compatible with the PIM. For that, we solve the following program:

$$(\widehat{v}, \widehat{\gamma}) = \underset{\{v,\gamma\}\in\mathbb{R}^{+2}}{ArgMin}\, \frac{1}{T}\sum_{t=1}^{T}\left[v\,(1+\gamma)^{t+1}\,X_{j,t+1} - (1-\delta_j)\,v\,(1+\gamma)^t\,X_{j,t} - I_{jt}\right]^2 \tag{9}$$

under the constraints:

$$v\,(1+\gamma)^t\left[(1+\gamma)\,X_{j,t+1} - (1-\delta_j)\,X_{j,t}\right] \leq I_{jt} \quad \forall t = 1,..,T \tag{10}$$

These T constraints impose that, for all the considered dates, the monetary increases of stocks, taking into account the depreciation, cannot be more important than the investments. We exclude the case when one invested dollar produces a capital of more than one dollar. Given the estimated parameters $\widehat{v}$ and $\widehat{\gamma}$, we can compute a sequence of increases (net of depreciation) in available stocks according to the formula:

$$
\begin{aligned}
\Delta \widehat{K}_{j,t+1} &= \widehat{K}_{j,t+1} - (1 - \delta_j) \widehat{K}_{jt} \\
&= \widehat{v} (1 + \widehat{\gamma})^{t+1} X_{j,t+1} - (1 - \delta_j) \widehat{v} (1 + \widehat{\gamma})^t X_{j,t}
\end{aligned} \tag{11}
$$

Finally, we can estimate the efficiency function by a non parametric method. More precisely, we use a LOESS regression[3] (Cleveland and Devlin, 1988) to estimate the link function between $\Delta \widehat{K}_{j,t+1}$ and I_{jt}, as:

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\Delta \widehat{K}_{j,t+1} = \widehat{f}_j (I_{jt}) \tag{12}
$$

For a given level of investments I_{jt}, the more the value of $\widehat{f}_j (I_{jt})$ is far from I_{jt}, the less appropriate is the estimation of capital stocks by the PIM.

3 Results

In order to assess the quality of our methodology, we propose to estimate the efficiency function of public investments in road and highways for the United States over the period 1951-1992. We use the series of public investments (Federal, State and Local) in road and highways, valued at historical costs expressed in millions of US dollars (source BEA). For the corresponding physical measures, we consider the total road kilometers (Canning, 1998). Figure 1 displays the estimated efficiency function and the corresponding 95% confidence interval. We can observe that the estimated function is relatively close to the straight line of $45°$ slope. For a low level of investments, the estimated efficiency function is statistically not different from the identity function. Consequently, for the United States, our approach does not show an important discrepancy between investments and the (net) variation of capital stocks. So, the PIM provides a good proxy of the public capital stocks effectively available.

When the same methodology is applied for the case of our two reference developing countries, the results are very different. Figure 2 displays the estimated efficiency functions for electricity, road and telecoms sectors in Colombia over

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[3]The principle of this regression is that a local polynomial is estimated for every reference point, using the points situated in the neighborhood of this reference point. The dimension of these neighborhoods is determined by a smoothing parameter which is defined by the rapport between the number of points included in the neighborhood and the total number of observations. The smoothing parameter was chosen according to a modified AIC criterion.

the period 1980-1994. It appears that the sector where public investments are the more efficient is the telecommunication sector. However, these comparative results must be very carefully used. Given data availability, our sectorial samples are very reduced. It implies that the estimates of the sectorial efficiency functions are relatively imprecise. So, in order to obtain more precise estimates, we propose an estimate of the global efficiency function based on the three sectors. More precisely, we report all the couples $\left(\widetilde{K}_{j,t+1}, I_{jt} \right)$ obtained for the sectors $j = 1, 2$ and 3 with $\widetilde{K}_{j,t+1}$, the net variation in capital stock. Given these observations, we estimate the global efficiency function $f\left(.\right)$, assumed to be homogeneous over the three sectors, by a LOESS regression.

$$\widetilde{K}_{j,t+1} = f\left(I_{jt}\right) \quad j = 1, 2, 3 \tag{13}$$

Figure 3 displays the estimated efficiency function for Colombia and Figure 4 displays the same function for Mexico. Both estimated functions are strikingly similar. They show that the "productive" component of public investments is largely overvalued when the PIM is used. Two results are particularly interesting here. Firstly, the estimated function is near a straight line. This conclusion is robust to the choice of another information criterion as the general cross validation (GCV) function. It implies that the estimated function can be approximated by a simple linear functional form $f\left(I_t\right) = \alpha\, I_t$ where α, with $0 < \alpha < 1$, denotes an efficiency parameter according to the expression proposed by Pritchett (1996). In other words, the relative efficiency, defined as the ratio of the "productive" investments to the total amount of investments, is constant. Secondly, the coefficient of the linear regression of $\widetilde{K}_{j,t+1}$ to I_{jt} is equal to 0.38 in the case of Colombia and 0.40 in the case of Mexico. According to this evaluation, one peso of public investments creates around 0.40 pesos of public capital in our reference sectors. So, our conclusions based on these non parametric estimates are similar to that of Pritchett (1996).

4   Conclusion

It is recognized that in a typical developing country, an important part of public investments may be inefficient in creating capital. Consequently, the perpetual inventory method, based on monetary investment flows, may overvalue the public stocks. So, we propose an original non parametric approach to evaluate the efficiency function that links variations (net of depreciation) of stocks to public investments. We consider four sectors (electricity, telecommunications, roads and railways) of two Latin American countries (Mexico and Colombia). We show that there is a large discrepancy between the amount of investments and the value of increases in stocks. Moreover, the estimated efficiency function is almost linear: the ratio of "productive" investments to the total investments is constant and equal to 0.38 in the case of Columbia and 0.40 in the case of Mexico.

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Table I. Annual Depreciation Rates by Categories[4]

Categories	Equipment	Structures	Depreciation Rate
Road	—	0.0202	0.0202
Railways	0.0589	0.0275	0.0328
Electricity	0.050	0.0211	0.0260
Gas	—	0.0237	0.0237
Water	—	0.0152	0.0152
Telecoms	0.1375	0.0237	0.0429

Note: For each asset, the depreciation rate is defined as a weighted average of the corresponding rates used for equipments and structures. The depreciation rates for equipment and structures are taken from Bureau of Economic Analysis (2003), table C, page M-31.

Figure 1 Non-Parametric Estimated Efficiency Function of Public Investments in Streets and Highways. United States, 1951-1992 (US$ million, Historical Cost)
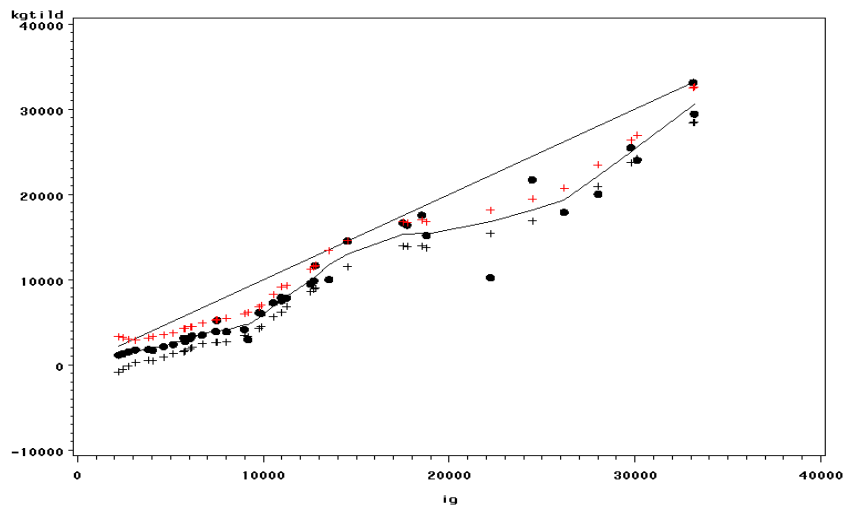
Notes: For each estimated point, the corresponding 95% confidence limits are represented by a sign "+"

Figure 2. Non-Parametric Estimated Efficiency Functions of Sectorial
Public Investments. Colombia, 1980-1994 (US$ million, current prices)
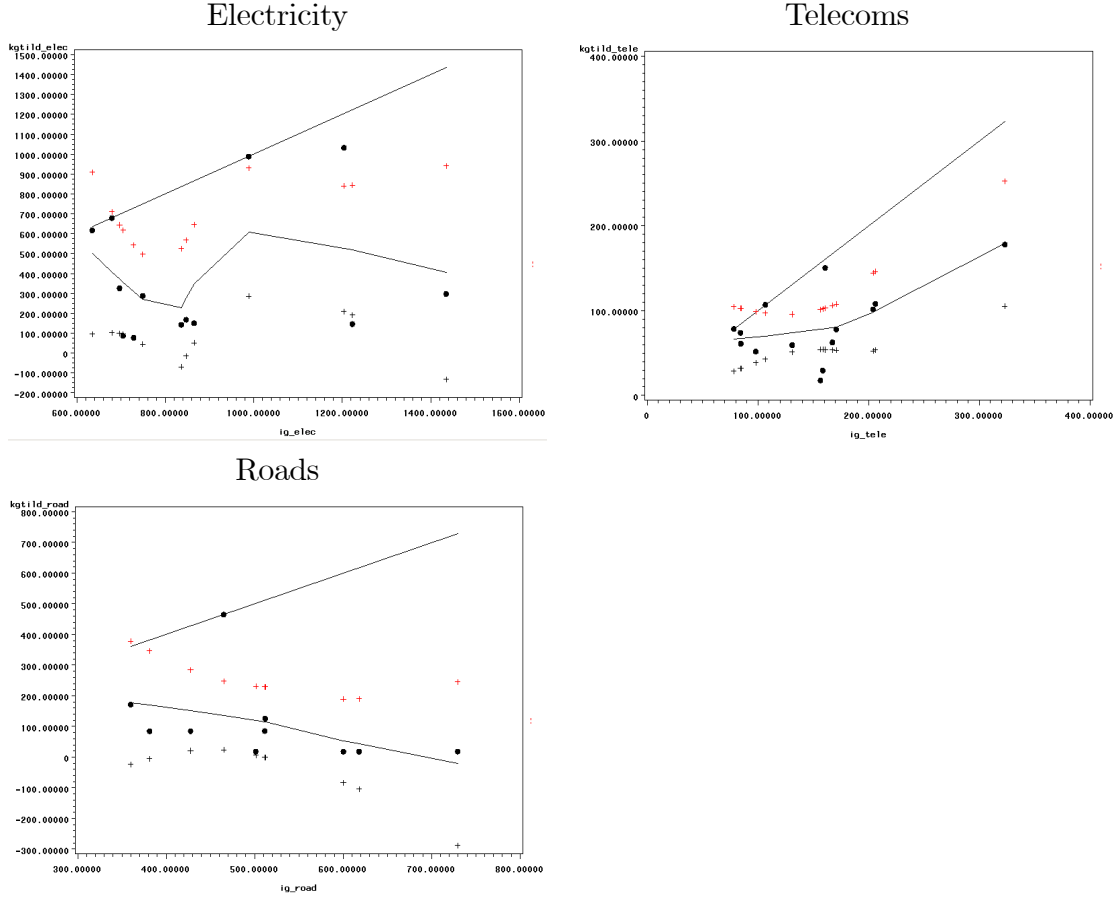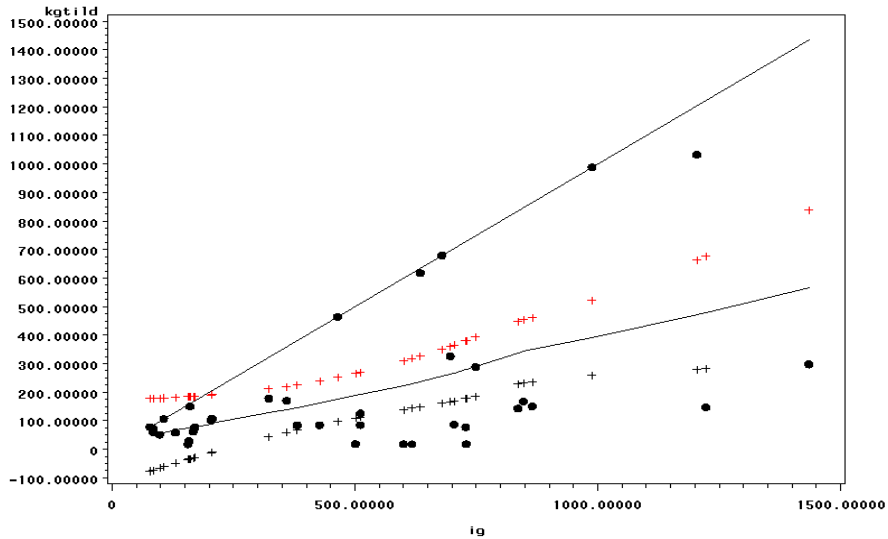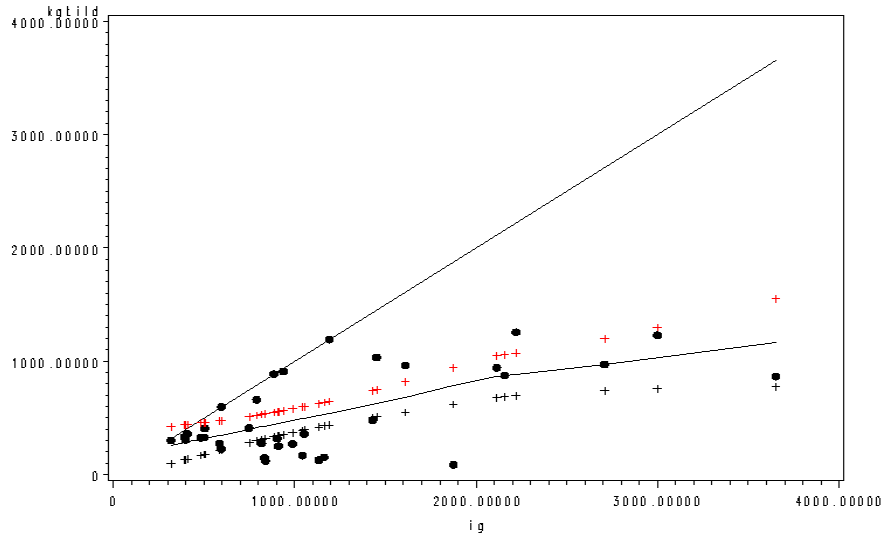
Electricity

Telecoms

Roads

Figure 3. Non-Parametric Estimated Efficiency Function of Total
Public Investments. Colombia, 1980-1994 (US$ million, current prices)

Notes: For each estimated point, the corresponding 95% confidence limits are represented by a sign "+"

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Figure 4. Non-Parametric Estimated Efficiency Function of Total
Public Investments. Mexico, 1980-1994 (US$ million, current prices)