Local Natural Resource Curse?*

Lars-Erik Borge† **Pernille Parmer**‡ **Ragnar Torvik**§

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Abstract

We extend the literature on the resource curse in two directions. First, using data for income derived from hydropower production in Norwegian municipalities we test the 'rentier state' hypothesis; that income derived from natural resources should harm efficiency more than income derived from other sources. Although we do find that higher municipal income reduces the efficiency in production of public goods, we do not find that this effect is stronger for resource income than for other income. Second, to obtain a purely exogenous measure of resource abundance we instrument income from hydro-electrical power by topology, average precipitation and meters of river in steep terrain. Thus our instruments can not themselves be the result of economic decisions, and therefore are exogenous. When instrumenting for resource abundance, we find that the efficiency reducing effect of natural resource income is stronger than what one would conclude based on OLS-estimates.

Keywords: resource curse, municipalities, political economy.

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*Prelliminary and incomplete. We are grateful for comments and suggestions from .

†Norwegian University of Science and Technology, Department of Economics, Dragvoll, N-7491 Trondheim, Norway; E-mail: lars.erik.borge@svt.ntnu.no

‡Norwegian University of Science and Technology, Department of Economics, Dragvoll, N-7491 Trondheim, Norway; E-mail: pernille.parmer@svt.ntnu.no

§Norwegian University of Science and Technology, Department of Economics, Dragvoll, N-7491 Trondheim, Norway; E-mail: ragnar.torvik@svt.ntnu.no

1 Introduction

A number of studies within the so-called 'resource curse' literature argue that public income derived from natural resources has perverse effects for economic efficiency and income. Several theories has been put forward to explain why this could be the case, and a large number of empirical papers investigate the potential mapping from resource abundance to bad economic performance. In this paper, by using data for income from hydro-electrical power plants in Norwegian municipalities, we aim to extend this literature in two directions. First, this data allows us to ask if the efficiency effect of natural resource abundance is *different* from the efficiency effect of other types of income. We find that there is support for a claim that higher income retards efficiency, but do not find support for the 'rentier state' claim that natural resource income damages efficiency more than income derived from other sources. Second, by using geographical characteristics such as meters of river, steepness of terrain and average precipitation as instruments, we arrive at a measure of resource abundance which is exogenous. Compared to IV-estimates, we find that OLS-estimates *understates* the damaging effects of resource income on efficiency.

The first known example of the resource curse is probably the effect of silver and gold from the American colonies on the Spanish state. According to North and Thomas (1973) these incomes freed the state from the constraints of the parliament, leading to a concentration of political power which had economic consequences that is partly to blame for the decline of Spain in the seventeenth century. North and Thomas's example is closely linked to the theories of the 'rentier state', a term first used by Mahdavy (1979) to explain why states that did not have to rely on domestic taxation of their population would be less accountable to their citizens, and to argue that the effect of this was poor political and economic development. The rentier state hypothesis can actually be seen as the inverse logic of the 'no taxation without representation' demand of the North American British colonies in the mid eighteenth century. According to the rentier state hypothesis, since resource abundance reduces the need for taxation of citizens it decreases the demand for accountability, and allows less efficient policies to persist. In its nature, the rentier state hypothesis argues that income from natural resources has different and less favorable effects than income derived from taxation of citizens. In contrast, the large empirical literature on the resource curse does not investigate the relative effect of resource income versus other public income, but rather looks the isolated effect of resource abundance.[1] Thus it should also have some interest to compare the efficiency effect of resource income with the efficiency effect of income derived from taxation.

The empirical literature on the resource curse is an area of intense debate. Since its

[1]This is not meant as a critique of that literature, as authors in this tradition do not claim to investigate the rentier state hypothesis. For more on the rentier state hypothesis see the overview in Ross (1999). For reviews of the resource curse literature, see Deacon (2011), Frankel (2010), and van der van der Ploeg (2011).

change in focus from case-studies such as Gelb (1988) and Karl (1997) to multicountry regressions following Sachs and Warner (1995), main challenges have been the possibility of omitted variables as well as the endogeneity of measures of resource abundance. To address the omitted variables problem a number of papers such as Aslaksen (2010), Collier and Goderis (2008),have investigated panel data that allows for country or local government fixed effects. The problem of endogeneity of the resource abundance measure has been more challenging. The initial literature such as Sachs and Warner (1995) and Mehlum et al. (2006) used flow measures such as share of natural resources in exports or in GDP. Other literature such as Gylfason (2001), Roland and Hodler (2006), Brunnschweiler and Bulte (2008a,b) and Conrad and Alexeev (2009) has used stock measures such as the share of natural capital in total capital or the value of subsoil assets. The measures of flow and stock variables can clearly be claimed to be endogenous. A reduction in alternative exports, a reduction in GDP or a reduction in physical or human capital means that a country is measured as more resource abundant. Countries with weak institutions or strong underdevelopment may have few other income possibilities than exploitation of natural resources, but they may also have discovered less of their subsoil reserves. For instance, Collier (2010) compares the value of known subsoil assets per square kilometer in countries with high GDP to those with low GDP. In the former countries the value of known subsoil assets is four times the value in the latter. The rich and developed countries simply has had more time to discover their resources, and thus even if more has been extracted, their measured resource wealth is higher. In these and other ways flow and stock variables of resource abundance may result in a too pessimistic or a too optimistic view on the economic effects of resource abundance.

Recently researchers have therefore increased attention towards finding more exogenous measures of resource abundance. Tsui (2011) use initial oil endowments to instrument for oil discoveries. Monteiro and Ferraz (2010) use a geographic rule that determines the share of oil revenues that accrue to different Brazilian municipalities. Caselli and Michaels (2011) use municipal oil output to instrument for municipal revenues in Brazil. We complement these studies by extending the resource curse literature to allow for a pure exogenous measure of resource abundance that can not depend on any economic decisions. Thus our paper is also related to the growing literature that uses geographical characteristics in empirical analysis. Geographical variables are often a good source for exogenous variation and may serve as well behaved instruments. Duflo and Pande (2007) use the river gradient as instrumental variable to study the productivity and distributional effects of large irrigation dams in India, and investigate how dams affect welfare in affected districts. A comparison of outcomes in regions with and without dams is unlikely to provide casual estimates. Regions with relatively more dams are likely to differ in other dimensions, as for example potential agricultural productivity. Their idea is that the river gradient affects districts suitability for dams, and they find positive effects in districts located downstream from a dam, but negative effects in districts where the dam is located.

Another study by Lipscomb et al. (2011) studies development effects of electrification between 1960 and 2000 using geological placement of hydropower plants in Brazil. Electrification is most probably correlated with unobservable effects like political decisions and other demand side concerns. They address this potential problem by isolating the portion of variation in electricity grid expansions attributed to "exogenous" engineering cost considerations. Hydropower plant placement is predicted based on geological characteristics like river gradient, water flow, and distance to the Amazon. Their results indicate a positive effect of electricity on some aspects of productivity.

Rural electrification has also been studied by Dinkelman (2010). She estimates the impacts of electrification on employment growth in South Africa. To identify the causal effect of electrification, land gradient is used as instrument variable for project placement, generating exogenous variation in electricity project allocation. The empirical analysis show significant effect on employment, indicating that studies that ignore employment effects could be missing important economic impacts if the infrastructure has a home production bias.

The rest of the paper is organized as follows. In Section 2 we discuss relevant institutional characteristics of the Norwegian local governments, while in Section 3 we discuss the potential for hydro-electrical power production. In Section 4 we clarify our hypothesis, in Section 5 discuss our data, and in Section 6 our instrumentation strategy. The empirical results are given in Section 7, and concluding remarks are offered in Section 9.

2 The Norwegian local governments

To credibly estimate the economic and political effects of resource abundance we run a within country analysis with the 430 local governments in Norway. These differ greatly in their resource abundance. Municipalities with suitable topological and geological characteristics may gain great incomes from hydropower production. This income source will be used as a measure for hydropower resources within each local government. In general the Norwegian municipalities face the same institutions, political system, and culture. The possible omitted variable bias in cross country analysis will thus be considerably reduced. The concerns regarding endogeneity in the resource measure will be addressed by an instrument variable approach using exogenous variation in topological and geological characteristics.

All Norwegian municipalities are administrated by a directly elected municipal council, ruled by a mayor and an executive board. There is an election at the local level every fourth year. This way the municipalities are partly local organizations with democratic institutions, and partly agents of the central government. The municipalities are the main providers of welfare services, i.e. education, health, and social services [2]. The services offered are regulated and based on national laws, and equalization of the services is a central goal of the Norwegian welfare state. The municipalities also operate under economic constraints set by the central government.

The local governments are heavily regulated on the income side. In general the central government determines the income of each local government by general grants, tax rate restrictions, and a income tax equalization program. The equalization program aims to bring per capita tax income within a local government closer to national level [3]. This imposes an almost exogenous budget constraint on the municipalities, where the central government has set the local public spending. Although some grants are earmarked, the municipalities decide the allocation of most of the budget between different services. About 50 percent of total block grants and local taxes is so called free-to-use-income. On the other side there are other income sources. For example may municipalities with hydropower production earn great gains from production. In 2007, local government income amounted to 12,7 % of GDP Mainland-Norway [4]. Efficiency in the use of local government income is obviously an important issue.

3 Hydropower in Norway

Hydro-electrical power production depends on water flow and height of fall given by the nature. Norway has been blessed with both of these characteristics through her climate and topology. In 2008 hydropower constituted to about 96 percent of the power production in Norway. The same year the power supply sector in total accounted for about 3 per cent of mainland GDP. In a global perspective, Norway is the sixth largest hydropower producer[5]. According to the Norwegian Water Resources and Energy Directorate approximately 60 percent of the total hydropower potential has been developed [6]. In later years several waterfalls have been protected against development of hydropower plants [7]. The first hydropower plant in Norway (and Europe) was built as early as in 1885. Since then there has been a great increase in the number of power plants and accumulated production capacity. Most of the enlargement was done between 1950 and 1990. During the last 25 years there have only been some small new installations, owing to the fact that environment and landscape effects have been more important in the concession approval. Yet, the

[2] Secondary education is provided at county level, hospitals is provided at state level.

[3] See appendix F.

[4] Or 16.7 % of BNP.

[5] In 2009. See: (Norwegian web page)
$http://www.nve.no/no/Energistatus-2008/Energiproduksjon/$

[6] In 2010. See: (Norwegian web page)
$http://www.nve.no/no/energi1/fornybar-energi/vannkraft/$

[7] For example is 3 of Norway's 10 highest waterfalls permanently protected against hydropower development.

production capacity has increased in the same period through technological improvements on already established power plants (Erlandsen, 2006).

The price formation for hydropower in Norway is primarily determined by supply and demand in the Nordic power market, but also by the power balance in countries outside this region. Precipitation and inflow to reservoirs are important for potential aggregate production and therefore also for prices. In addition temperatures and other weather conditions affect the supply and demand of electricity, and will be important for the price formation in the electricity market.

3.1 The Hydropower Process

There are about 4000 river systems in Norway. These systems comprise rivers and all its tributaries from source to sea, including lakes, snowfields and glaciers. Water inflow depends on the river system and precipitation. The catchment area is the geographical area that collects the precipitation that runs into a river system. Volume and head of water determine the potential energy of a waterfall and therefore the locations of hydropower plants and their potential [8]. There are two main types of hydropower plants developed in Norway. Firstly, western Norway, Nordland county and parts of Troms county has relatively steep water systems with steep waterfalls. Here high-head power stations are mainly developed . These plants are constructed to utilize a large head but smaller volume of water. Many of these plants are reservoir power stations, and store water in a reservoir. Water is directed into pressure shafts leading down to the power plant, where it strikes the turbine runner at high pressure. The kinetic energy of the water is transmitted via the propeller shaft to a generator, which converts it into electrical energy (Norwegian Ministry of Petroleum and Energy, 2008). Reservoir power stations allow water to be retained in flood periods and be released in drought periods. See the illustration of a high-head power station in Appendix D. To increase the hydropower production potential, water is commonly transferred from one part of a river system to another, or sometimes even between neighboring river systems (as shown in the same figure). Numerical, the production potential of a hydropower plant equals:

$$N(kW) = g \cdot \eta \cdot Q(m^3/s) \cdot H(m) \tag{1}$$

Here g equals the acceleration of gravity (9.81 m/s^2), η is the total power efficiency of the power plant, Q the maximal usable water flow, and H is the total height of fall.

Secondly and in contrast, eastern Norway, Tronderlag region and Finnmark county has longer water systems that carry a large water volume but with relatively smaller waterfalls. Then it is often developed low-head power stations, which use large water volume but

[8]The head of water is the height difference between reservoir intake and power plant outlet.

smaller heads. Most low-head stations are run-of-river power stations. Regulations of the water flow are difficult, so water production varies with the incoming water given by nature. For both high- and low-head power stations there is often several stations in the same river system.

There are other cost considerations related to the hydropower process, as for example costs of transporting electricity, and variation related to demand. The focus in this paper is the topological, geographical and the climate factors that determine where hydropower plants are built.

4 Empirical specification and hypothesis

Municipalities with hydropower production potential may earn considerable profits if they are affected by hydropower developments. An interesting hypothesis is to analyze if the municipalities with hydropower abundance use the extra income to offer better local services, or if these municipalities is exposed to the so called *natural resource curse*, and become less efficient given their income. To study this hypothesis we need a measure for local public productivity, as will be discussed in section 5.1. A productive (efficient) local government is defined as a local government where the aggregated local public service production is relatively high compared to economic resources. A rich local government has the potential to supply relatively better and more public services to their inhabitants. But as emphasized in the rentier state literature the composition and size of income may also affect productivity. A local government with high income may supply a high level of public services, even if the use of the economic resources is not efficient. A high level of public income may reduce the incentives to use the available resources efficient. When a local government has high income from hydro-electrical power plants its need to raise alternative income from other sources decrease, possibly making citizens less concerned about how 'their' money is used. In turn, weaker monitoring of politicians may induce inefficiency. Thus following Borge et al. (2008) efficiency in public service provision can be understood as a principal-agent problem. Production is delegated to a service producing agency (bureau) by the politicians (sponsors). The agency is better informed about costs and will prefer a slack budget. Budgetary slack allows non-productive activities, including low effort, over-employment and extra salary. This conflict of interest may result in inefficient services supplied by the municipalities.

Our econometric specification will be as follows:

$$\begin{aligned}\text{Efficiency}_{jt} = \alpha &+ \beta_1 \text{HydroRevenue}_{jt} + \beta_2 \text{OtherRevenue}_{jt} \\ &+ \beta_3 Z_{jt} + \delta_t + \epsilon_{jt}\end{aligned} \tag{2}$$

Here $\mathit{Efficiency}_{jt}$ is efficiency in local government j in year t, $\mathit{HydroRevenue}_{jt}$ is income from hydropower resources per capita, $OtherRevenue_{jt}$ is local government income per capita excluded hydropower income, Z_{jt} is a vector of explanatory variables as described in section 5.3, δ_t is a year-specific constant term, and last the error term ϵ_{jt} that consist of a time invariant local government effect and an idiosyncratic error term. All variables will be discussed in next section.

Our hypothesis within this framework will take two forms. The first we refer to as the *Paradox of Plenty*; namely that much income in a local government reduces the efficiency in the production of public services, but that it is total income and not its composition that matters for efficiency. Thus the *Paradox of Plenty* hypothesis can be formulated as

$$\beta_1 = \beta_2 < 0.$$

The other hypothesis we refer to as the *Rentier State* hypothesis; income derived from resource abundance has a more damaging effect on efficiency that income derived from other sources. Thus the *Rentier State* hypothesis can be formulated as

$$|\beta_1| \;>\; |\beta_2|.$$

These hypothesis will be studied and discussed, but first we need to present and discuss the data for the empirical analysis.

5 Data

Our panel dataset consists of Norwegian municipalities in the period 2001-2007. The productivity measure is collected from annually reports by the Norwegian Advisory Commission on Local Government Finances[9]. Most financial variables are from Statistics Norway. Topological and geographic variables is collected from The Norwegian Meteorological Institute, Norwegian Water Resources and Energy Directorate, and Norway Digital - the national geographical infrastructure. The topological and geographical variables is transformed in ArcGIS. See appendix A for variable description. Municipalities that changed borders during the data period is dropped, which affects 10 municipalities.

5.1 Dependent variable

We will use a productivity measure at local government level for the period 2001-2007, developed by Borge et al. (2008) as dependent variable. Observations vary between 357 and 387 for different years, with a total number of observations equal to 2592. This covers approximately 86 % of all municipalities on average.

[9]TBU: Det tekniske beregningsutvalg for kommunal og fylkeskommunal okonomi

Efficiency is measured as the ratio between total output and available resources. The efficiency measure is global in the sense that it relates to overall service provision. To measure output, we use an aggregate output measure developed by the Norwegian Advisory Commission on Local Government Finances [10]. The output measure is based on indicators of production from six service sectors: care of elderly, primary and lower secondary education, day-care, welfare benefits, child custody and primary health. According to Borge et al. (2008) the six sectors account for about 75 % of the local government budgets. In all sectors, service provision is arranged by the local government. In cases of outsourcing, private production financed by the local government is included in the output measure. All sectors are in general weighted after their budget share. The measure relies on a total of 17 indicators of production from the different service sectors. Also sector specific indicators are weighted after budget information, if available. The calculation of the aggregate output measure is as follows:

$$Output_j = \sum_{s=1}^{S} \left(\alpha_s \left(\sum_{i=1}^{I_s} \beta_{si} \frac{x_{si}^j}{\bar{x}_{si}} \right) \right), \qquad \sum_{s=1}^{S} \alpha_s = 1, \quad \sum_{i=1}^{I_s} \beta_{si} = 1, \tag{3}$$

Here x_{si}^j is indicator i in sector s in local government j, $\bar{x}_{si}$ is the weighted (by population size)sample mean, and α and β are, respectively, sector and indicator weights.

Next step is to form the efficiency measure. Efficiency is measured as output given economic resources. Economic resources is measured by per capita income within the local government, and is explained in detail in section 5.2. Efficiency in local public services is then given as:

$$\text{Efficiency}_{jt} = \frac{\text{Output}_{jt}}{\text{TotalRevenue}_{jt}} \tag{4}$$

Both $Output_{jt}$ and $TotalRevenue_{jt}$ are given a weighted average of 100, using population size as weight. Their numerical values of each observation can therefor be interpreted as deviation from the means in percentage terms.

Figure 3 plots $Output_{jt}$ and $TotalRevenue_{jt}$ for 2009 in the same graph. It is clear that there is a positive relationship between aggregate output and local government income. There is also a substantial variation in aggregate output between municipalities with similar levels of income. This indicates that some municipalities is more efficient that others, given the same income per capita level[11].

[10] In Norwegian: Det tekniske beregningsutvalg for kommunal og fylkeskommunal okonomi, (TBU).

[11] And then income are adjusted for differences in costs between municipalities, as will be discussed in section 5.2.

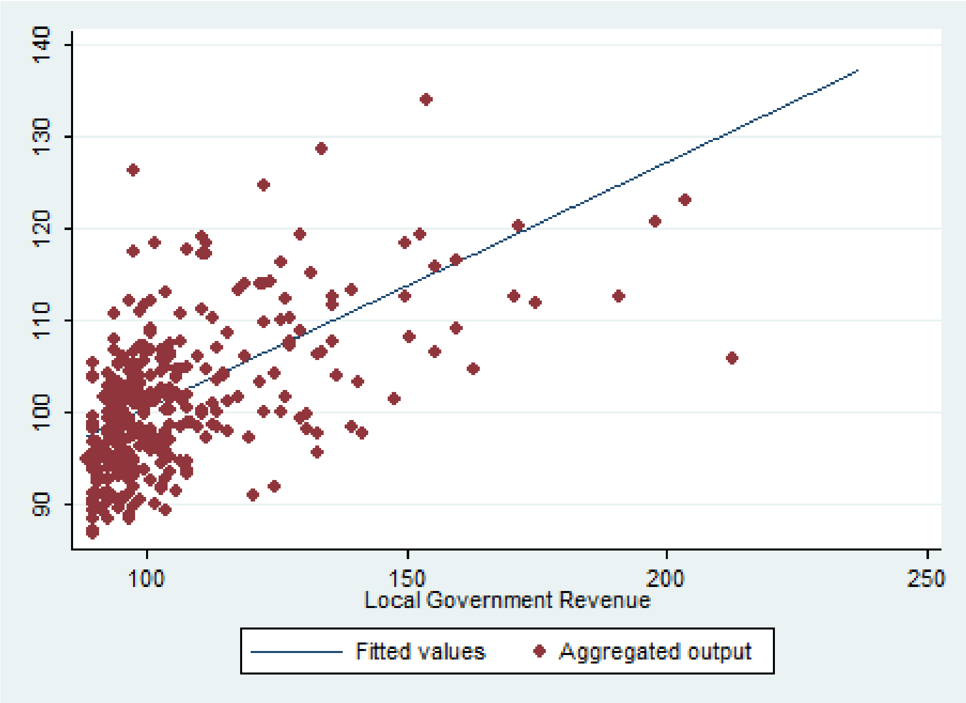

Figure 3: Aggregate output and local government income, 2007. Note: Output and income are normalized such that the weighted average equal 100. Bykle local government is dropped to ease visual interpretation of the plot.

5.2 Local government income

We differ between three different income measures in this paper; $TotalRevenue_{jt}$, $OtherRevenue_{jt}$ and $HydroRevenue_{jt}$. At local level costs is equalized in some extent for unfavorable cost conditions [12]. Therefore, in order to capture the real differences in income between municipalities, all income measures are "deflated" by the cost index from the spending needs equalization system. If the income variable is not deflated, it is possible to (incorrectly) conclude that an "efficient" local government is "inefficient". The income are also corrected for payroll taxes, which varies between districts in Norway.

First, $TotalRevenue_{jt}$ equals the sum of block grants, capital tax, income tax, property tax, natural resource tax and concession power income. After it has been deflated by the cost index and corrected for payrolls taxes it is given a weighted average of 100, using population size as weight. This measure is used to calculate the efficiency measure. All data is collected from Statistics Norway.

[12]This cost equalization concept is similar to the income equalization program discussed in appendix F. The goal is for all municipalities to be able to offer equal public services. Municipalities with less costs than the national average cost level will redistribute some of their income to municipalities with relatively high costs given average costs. The cost level of local public services is calculated individually for all municipalities given expenditure weights and certain criteria. This includes unfavorable cost conditions related to population size, settlement pattern, the age composition of the population, and social factors.

The two other income measures are used as explanatory variables in the regressions. $OtherRevenue_{jt}$ is equal to all income except income from hydropower. This measure is not weighted, but is deflated by a local government specific deflator to capture inflation over time [13]. See Appendix A for more. The third income measure is hydropower income, as will be discussed in next section.

Local government income from hydropower

Hydropower resources for a given local government may be measured by the income collected from the producers. These income are from six different sources: property tax from hydropower plants, natural resource tax, concession power, concession fees, income from reversions, and business development funds. First, municipalities are free to impose a property tax on the power plants, as most of the municipalities that has hydropower production do (but not all). They can also decide the tax rate, but must be set between 0.2 or 0.7 percent. The property tax income may be used freely by the local government. Data for property tax from hydropower plants is collected from Norwegian Tax Administration. Second, the natural resource tax equals 0.11 NOK/kWh. This tax falls into the income equalization program, the remaining amount after income redistribution may be used freely. Third, municipal authorities affected by hydropower development are entitled to buy up to 10 per cent of the power generated. The yield from this concessionary power is equivalent to the difference between the market price of power and the price for the concession power including the input tax [14]. Fourth, the concessions fees represent compensation for damage caused to districts in which water resources are exploited. The fee enters into a distinct fond that is used to improve the industry and commerce within the local government. Next, the fifth income source is the income from reversions. The State has the right of reversion of a power plant when a license expires, usually after 60 years. The municipalities that are affected by this reversion can claim up to $\frac{1}{3}$ of the ownership or the dividend. These transfers are often earmarked and locked up in a fund. The last and sixth income source is the business development funds that may be imposed on the licensee. The purpose of this fund is to strengthen local industrial and commercial development which may be affected by the hydropower development. See Appendix A for detailed description. It is important to mark that income from hydropower is distributed between municipalities affected by the production. The income distribution rules of the income variables is discussed in Appendix E. How many municiaplities that has income from hydropower production in our sampel varies from year to year. It varies from a about 37 percent of the sample size in 2001 to over 50 percent of the sample in 2007.

In this paper we focus on the three first income components from hydropower. $HydroRevenue_{jt}$ is equal to the sum of property tax from hydropower plants, natural

[13] The deflator is collected from *Ministry of Local Government and Regional Development*

[14] Input tax: tax claimed when transporting electricity in the power grid.

resource tax and concession power income [15]. As for $OtherRevenue_{jt}$, this measure is not weighted, but is deflated by a local government specific deflator to capture inflation over time.

5.3 Other explanatory variables

Other factors than income may affect the productivity within a local government, and need to be controlled for. Factors like democratic participation, political leadership, private income, and costs related to topology and climate may all be important to productivity in local public services. We briefly discuss the other included explanatory variables here. First we control for population size. A large population may make it harder to administrate in an effective way. Second, we include a variable for sparsely population. Settlement patterns may increase public service costs. Third, as the income variable only includes block grants and local taxes, it does not intercept the effect of income from user fees on productivity. It is possible to capture some of this effect by including private gross income. High private income may carry high user fee income. Forth, democratic participation can be measured by voter turnout in local government elections. A high degree of democratic participation may reduce inefficiency in public service provision through strict monitoring of politicians. On the other hand strong democratic participation may have a negative effect on efficiency if the voters vote for leaders that promise not to enforce "unpopular" efficiency-improving policies. Finally, topological and climate factors may affect the productivity. We include a variable for precipitation deviation from normal values. Years with more precipitation than usual may force higher costs on the municipalities. Also a variable for deviation in temperature from normal values is included.

6 Empirical strategy

We will run both simple Ordinary Least square (OLS), Fixed Effects (FE) and Instrumental Variable (IV) regressions. We find consistent and significant results for all specifications. FE will remove differences between municipalities that do not vary over time, but that may affect productivity, as for example; topology, geography and normal weather conditions. To investigate if our findings are causal it is necessary to use IV regressions. Hydropower income is in general endogenous and will depend on the policies chosen by politicians in response to fiscal needs. The identification process will be discussed in the next section.

[15] There is two reasons for this. First, all of these income can be used freely by the local government. Parts of the natural resource tax will first be distributed in the income equalization program, see Appendix E. The remaining income may then be used freely. Second, we have good data for these three components. Also, in 2007, property tax from hydropower plants, natural resource tax and concession power income accounted for over 90 % of the hydropower income for municipalities (excluded developmentfunds, there is no data for this variable).

Pooled regressions may underestimate the standard errors and thereby overestimate the t-values. We therefore report t-values based on clustered standard errors taking into account that the error terms from the same local government are correlated.

6.1 Identification Strategy

There are two identification problems likely to affect our estimations. Firstly, there are a potential for omitted variables. It is likely that hydropower income is correlated with unobservable municipal-specific characteristics, as for example political factors and the inhabitants preferences. The sign of omitted variables bias is not predictable. Secondly, it is likely that the observed hydropower income variable to be endogenous. One argument may be that "lazy" municipalities make an effort to increase their hydropower income instead of improving the overall productivity. One way to easily increase hydropower income is to enforce property tax on the hydropower plants, a decision made at local level. The property tax rate is also set by the local government, but must be between 0.2 and 0.7 percent.

These problems will be addressed by an instrumental variable strategy. We explore the fact, well documented in the hydropower plant literature, and described in section 3.1, that rivers in steep terrain, water volume in the river, and volume of precipitation within the catchment area affect the ease of a hydropower plant construction.

A valid instrument must satisfy three main criteria. First, the instrument must be randomly assigned. Second, the exclusion restriction states that the instrument should only effect the explanatory variable and not the dependent variable. Third, a strong fist-stage relationship is important (Verbeek, 2008). The first and third assumption is satisfied in our analysis. All instruments should be randomly assigned and our first-stage relationship is strong as shown in Appendix ???.

The exclusion restriction needs to be further discussed. Local public productivity should not be strongly correlated with any of our instruments. On the other hand, there may be argued that municipalities with heavy snow fall during winter may have some efficiency loses. We argue that our empirical specification is crucial in order to satisfy the exclusion restriction. By applying FE we will rule out the effect of municipalities with heavy snowfall on average. But precipitation vary from one year to another. We therefor control for the deviation in precipitation from normal values in each local government. In addition, we include deviation in temperature from normal values as a explanatory variable.

In total, our instrument seems to satisfy all criteria for a good instrumental variable. Nevertheless, all instrument variable estimations must be interpreted with caution. While there is no guarantee that the instruments are valid, by comparing how the estimates changes with these modifications, we obtain some sense of the magnitude and direction of bias in our estimates.

However, an underlying identification assumption in our analysis is that, in absents of hydropower income and given all other explanatory variables, productivity outcomes across municipalities should not have any systematically differences.

First-stage

Our instrument needs to be explained, as there are many components to it. The first stage equation for IV estimation takes the form as shown under:

$$\text{HydroRevenues}_{jt} = \sigma + \phi_1 HydroPotential_{jt} + \phi_2 Z_{jt} + u_t + w_{jt} \tag{5}$$

Here u_t is a year-specific constant term that captures any common effects that vary over time, Z_{jt} represent other explanatory variables from the second stage regression, and w_{jt} is the error term. The instrument, $HydroPotential_{jt}$, equals:

$$\begin{pmatrix} Hydro \\ Potential \end{pmatrix}_{jt} = \frac{\left[\sum_{w=10}^{w=750}(w \cdot riv12_{wj}) + 0.2 \cdot \sum_{w=10}^{w=750}(w \cdot riv12N_{wj})\right] \cdot Prec_{jt} \cdot Res_t}{pop_{10jt}} \tag{6}$$

Here w is water volume classification, $riv12_{wjt}$ is meter of river with water volume class w in terrain above 12.8 degrees in the center local government[16], $riv12N_{wjt}$ is meter of river in terrain above 12.8 degrees in neighboring municipalities [17], $Prec_{jt}$ is average precipitation in the center local government and its neighbors, Res_t is average water level in all Norwegian water reservoirs, and at last pop_{10jt} is population size lagged 10 years.

The instrument uses different elements from the production process, discussed in chapter 3.1, to predict if a local government may have hydropower income or not. To remind the reader, hydro power income is divided between municipalities affected by the production, see Appendix E. We therefore include data for neighboring municipalities in the instrument.

Taking point of departure in equation (1) we have constructed a formula that captures the potential for hydropower income in the center local government. Fist, the idea is to multiply w, that represent the water volume in the rivers, with meter of river in terrain

[16] At this point of time, 12.8 degrees is the most accurate level of land slope that we have been able to calculate in ArcGIS. In near future we want to follow NVE and Norconsult (2003), that use 5 degrees. We expect to find the same results. Using 25 degrees gives us no significant changes in the results.
We refer to local government j at the center local government. See figure in Appendix G.1 for a graphic illustration.

[17] Neighboring municipalities are municipalities with borders to the center local government. See figure in Appendix G.1 for a graphic illustration.

above 12.8 degrees. We use data collected from the Norwegian Water Resources and Energy Directorate. They have classified all Norwegian rivers above 1 m^3/s into 10 classes. The variable w equals the maximum level in each class [18]. See Appendix G for data description and how these variables are calculated. This makes the instrument capture differences in level of hydropower income (hydropower production) between the municipalities. We also add the same for neighboring municipalities, but this is multiplied by 0.2 to show that production in neighboring municipalities do not generate as much income as production in the center local government itself. Next, we multiply this sum by average precipitation ($Prec_{jt}$) and average water level in all Norwegian water reservoirs (Res_t). Now the potential for production is multiplied by variables that give us some information about price and time variation. Average precipitation gives information about how much precipitation there is within a potential catchment area. The water level gives information about price fluctuations. Full reservoirs indicate high supply, this usually implies lower average prices. Power prices will affect hydropower income. Finally, all of this is divided by population size lagged 10 years, to get the instrument in per capita term. We lag the population size to make sure that there is no endogeneity problem between the instrument and the dependent variable. Municipalities with no rivers or neighbors will not gain any hydropower income in this instrument.

7 Empirical Results

The estimation results are presented in Table 1. As a starting point we report a simple OLS model with limited explanatory variables. It appears that both effects is negative and significant. But there is no significant difference between the the two coefficients of interest. This indicate that our *Paradox of Plenty hypothesis* developed in section 4 holds, and that the *Rentier State hypothesis* is rejected. The negative effect of an increase in hydropower income is only slightly greater in absolute value compared to the negative effect of an equal increase in other income. Next, adding other explanatory variables change the coefficients. In column 2, we report an OLS regression that includes all the other explanatory variables discussed in section 5.3. Indeed there is a negative effect of increased income on efficiency, but now the composition of income do matter. Even if the difference is statistically significant it is not economically significant. The difference is equal to 0.18 and indicate that an increase in $HydroRevenue_{jt}$ cause an additional reduction in efficiency equal to 0.18 percent points, compared to an equal increase in $OtherRevenue_{jt}$. The difference only account for 1.6 percent of the efficiency measure standard deviation. The results support the *Paradox of Plenty* hypothesis.

Before we discuss the results further, we will run a FE regression. It is likely that

[18] Classifications (m^3/s): 1-10, 10-50, 50-100, 100-150, 150-200, 200-250, 250-300, 300-400, 400-600, 600-750.

omitted variables affect our coefficients. The FE results are shown in column 3. By eliminating within local government variation that is invariant over time the results still stand, although the gap between the two coefficients is reduced. Both coefficients are strongly significant and negative. To emphasize the magnitude of the effect of hydropower income on efficiency; a standard deviation increase in $HydroRevenue_{jt}$ (equal to 2.8) reduce the efficiency by 2.77 percent points, everything else equal. This equals about 24 percent of the efficiency measure standard deviation. In comparison, given all other variables, a standard deviation increase in $OtherRevenue_{jt}$ (equal to 4.35) leads to a reduction in local public efficiency equal to 4.57 percent points. This account for about 41 percent of the efficiency measure standard deviation.

Although the change in coefficients are small from the OLS to the FE estimates, it confirms our suspicions that there are omitted variable bias in the OLS estimates.

Next, we test the causality of our result by an IV-strategy. A challenge is that, as argued, local income from hydropower production are not exogenous. Therefor, the causal effect from the FE regression is uncertain. We address this challenge by using an instrumental variable approach. The first stage regression is reported in Appendix B. Column 4 and 5 present respectively IV and IV/FE estimates. The results show that our results holds, and we can interpret our results as causal. We observe that the coefficients increase a bit in absolute value , indicating that OLS underestimate the effect of $HydroRevenue_{jt}$ and $OtherRevenue_{jt}$ on efficiency. Still, the gap between the two coefficients is small and equal 0.075. Again, this support our *Paradox of Plenty* hypothesis and not the *Rentier State* hypothesis.

Also other explanatory variables are statistically significant. A large population has a negative effect on efficiency in the OLS regression. In contrary, a population settled in sparsely populated areas has a positive effect on efficiency. These effects do however disappear in the FE and IV/FE models. This may be explained by limited time variation in both variables, which will make the FE estimates inaccurate. This may also be the case for private gross income. It has a positive and strongly significant effect on efficiency in the OLS regression, but also this effect becomes insignificant in the FE and IV/FE model. Surprisingly, voter turnout has a negative impact on efficiency, although not strongly significant. The last two explanatory variables included is precipitation- and temperature deviation from normal values. The coefficients are as expected negative. In years with heavy precipitation and/or low temperatures the efficiency decrease [19].

[19] Regressions including the Herfindahl-Hirschman index, average winter precipitation, and average gradient have been done. However, these variables had no significant coefficients and did not affect the other coefficients in the regressions.

Table 1: Regression results

Efficiency	(1) OLS	(2) OLS	(3) FE	(4) IV	(5) IV/FE
Hydro income	-1.085***	-1.184***	-0.990***	-1.273***	-1.308***
	(0.149)	(0.218)	(0.130)	(0.379)	(0.392)
Income ex. hydro	-1.083***	-1.364***	-1.050***	-1.343***	-1.233***
	(0.126)	(0.146)	(0.141)	(0.169)	(0.241)
Population		-0.003***	0.001*	-0.003***	0.001
		(0.001)	(0.001)	(0.001)	(0.001)
popSparShare		8.267***	-3.102	8.206***	-3.121
		(1.603)	(6.168)	(1.621)	(4.894)
Priv. gross income		0.003***	-0.002*	0.003***	-0.002
		(0.001)	(0.001)	(0.001)	(0.001)
Voter turnout		-0.127*	-0.123**	-0.117	-0.111*
		(0.064)	(0.043)	(0.070)	(0.047)
Temp.dev.		-3.344**	-1.818**	-3.456**	-1.764**
		(1.067)	(0.606)	(1.105)	(0.554)
Precip.dev.		-0.002*	-0.003***	-0.002*	-0.003***
		(0.001)	(0.001)	(0.001)	(0.001)
Constant	127.473***	175.619***	157.440***	175.908***	160.207***
	(2.659)	(14.581)	(8.479)	(14.731)	(8.599)
R-squared	0.326	0.460		0.459	
N	2583	2576	2576	2569	2569
Year dummies	YES	YES	YES	YES	YES
Clustered st.errors	YES	YES	YES	YES	NO[a]
Estimation period	2001-2007	2001-2007	2001-2007	2001-2007	2001-2007

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a]The results still holds if we cluster on municipalities using the Stata command *xtivreg2*, which is an extensions to Stata's official xtivreg. Only difference is that the F-statistics for the first stage is reduced to 9.31. This is still sufficient for having a strong first stage. See the first-stage regressions in Appendix 6.1.

8 Robustness

In this section we provide several robustness checks for our baseline estimates. Appendix C summarizes results from the alternative specifications that will be presented below.

First we investigate if our results are sensitive to extreme observations and outliers. The motivation is that there are a few observations with relatively low levels of efficiency. For example, in 2005, the minimum value for the efficiency measure is 45, but only 1 % of the observations are below 65. On the other end of the distribution, the maximum value is 135, but only 1 % of the observations is above 125. Also our hydropower income meassure has some exstreme maximum values. The maximum value in the sample equals 47 (1000 NOK), but only 4,4 % of all observations has a value above 5. It cannot be ruled out that some of the extreme observations reflect measurement error. It is therefor important to investigate if some of our results are driven by outliers. We rerun our FE and IV/FE baselinemodels with two alternative subsamples. Fist, only observations with efficiency between 80 and 120 are included. Second, only observations with hydropower income less than 5 is included. The results are presended om Appendix C, column 1-4.It appears that the results are very robust to the reductions of sample size.

Next, it is also of interest to see if the results hold if we only use observations from municipalities with hydropower income. This regressions is represented in column 5 and 6. The results are robust, but insignificant in the IV/FE regression. This may be caused by a heavy reduced sample size (from 2569 to 1084).

Another concern may be that municipalities with hydropower income typically is sparsely populated. In our baseline models we control for this by including an explanatory variable equal to share of population settled in sparsely populated areas. To test if this is sufficient, and that there is no other omitted population size variable that affect our estimates, we rerun our baseline regression with observations restricted to municipalities with less than 10,000 inhabitants. Column 7 and 8 show that the results remain unchanged.

It is possible that there is a time lag for hydropower income to affect local public efficiency. We test this by using our hydropower income measure lagged one period (one year). This reduce the time variation in our dataset from 7 to 6 years. There are some changes in the coefficients, but in general the results are unchanged. The significants of some of the coefficients are reduces, not unexpectedly due to the reduced time variation. (Results available on request.)

There is also of interest to include the efficiency measure lagged one time period. As shown in column 9 and 10, efficiency do tend to depend on future efficiency levels. This do however affect the size of other results in some degree, but our findings still stand. There is not a big difference between the two effects. Also, the coefficients are not significant, probably due to the reduces time variation.

In our baseline regression we cluster at local government level. A possible disadvantage of these standard error is that they do not allow for correlation across municipalities within the same state, witch may be important in practice [20]. As a simple robustness check we cluster at state level. The standard errors are reduced substantially, also the first-stage F-statistics is now improved. This is a natural result of a relatively small number of clusters (only 19 states), and may produce downward biased standard errors. The results remain the same, with strongly significant coefficient. (Results available on request.)

In total, all of the robustness test show that our results are robust. Due to relatively

[20]For example, a boom in an hydropower rich local government may attract in-migration from other municipalities within the same state, reducing total tax income in other municipalities. This may affect available economical incomes. This may in turn result in a negative correlation in local government level residuals within the same state.

short time variation in data (2001-2007), the FE estimations are sensitive to reduction of time variation.

Alternative Specifications of Instrument

It is of great importance for our identification strategy that our instrument is robust. To test the robustness of the instrument we use an alternative specification. Our alternative instrument will take the same form as in equation (6), but we now compute separate terms for the center local government and the neighboring municipalities. This way our first-stage is overidentified and we can test the exogeneity assumption with a Sargan-Hansen overidentification test. The instruments pass this test on a 10 percent significance level. All results is unchanged, and the first stage is still relatively strong with an F-statistics above 9 (results available on request.)

9 Concluding remarks

In this paper we have found support for the *Paradox of Plenty* hypothesis that higher municipal income retards efficiency, but there is no support for the *Rentier State* hypothesis that resource income has more adverse efficiency effects than other income sources. Moreover, we have used instruments for resource abundance which cannot possibly be affected by endogenous economic decisions.

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A Variable description and descriptive statistics

A.1 Dependant variable

Variable	Variable Description	Mean (st.dev)
Efficiency	Measures the ration between total output in local public services and available economic resources. See 5.1 for definition. *Source: the Norwegian Advisory Commission on Local Government Finances*	104.53 (11.12)

A.2 Local government income

Variable	Variable Description (Variables in 1000 NOK)	Mean (st.dev)
Total income	Equals the sum of; block grants, capital tax, income tax, property tax, natural resource tax and concession power income. After it has been "deflated" by the cost index and corrected for payrolls taxes it is given a weighted average of 100, using population size as weight. *Source: Statistics Norway and Norwegian Tax Administration*	23.15 (5.72)
Other income (ex.hydro)	$\text{OtherRevenue}_{jt} = \frac{block\,grants + capital\,and\,income\,tax + (prop.\,tax\,excl.prop.\,tax\,from\,hydro)}{[cost\,index/(1+payrolltaxrate)]} \times (deflator)$ *Source: Statistics Norway*	22.7 (4.35)
Hydro income	$\text{HydroRevenue}_{jt} = \frac{prop.\,tax\,from\,hydro + natural\,resource\,tax + concession\,power}{[cost\,index/(1+payrolltaxrate)]} \times (deflator)$ See next table for data description of the hydropower income. *Source: Statistics Norway and Norwegian Tax Administration*	0.805 (2.80)

A.3 Hydropower income at local government level

VARIABLE	VARIABLE DESCRIPTION (Variables in 1000 NOK)	MEAN (ST.DEV)
Property tax from hydropower plants	The Norwegian municipalities are free to impose a property tax on the production plants. The tax basis is calculated on the market value of the property. Because the market value of the property among other factors depends on the market price of hydropower over the last 5 years, so will the property tax. By law the minimum basis of the property tax is NOK 0.95 kWh, and the maximum is NOK 2.35 kWh. The tax rate is set between 0.2 and 0.7 percent. The property tax only applies to plants larger than 10000 kVA. The property tax is a pure municipality tax, and can be used as free assets. Yet, the county authority will take property tax income level into consideration when distributing other transfers. Source: Property tax basis is collected from Norwegian Tax Administration. Tax rate data is only available for year 2003, 2005 and 2007. Data for 2007 is collected from Statistics Norway for 2007, data from 2003 and 2005 is collected from The National Federation of House Owners in Norway. We set the tax rate in 2001, 2002 and 2004 equal to the tax rate in 2003. The tax rate in 2006 is set equal to the tax rate in 2005.	2210 (7721)
Natural resource tax	Applies to power stations. NOK 0.011/kWh is allocated to the municipality authority. The tax ensures that the local governments have a minimum tax income level. The tax base for this tax is calculated for each power plant, and is the average of the plant's total output of electricity in the income year and the six preceding years. As from 2004, the tax base includes only generators with a minimum output of 5500kwh. The natural resource tax enters into the income equalization program, by this it follows that parts of the tax will be redistributed through lower state transfers. *Source: Statistics Norway*	1433 (5438)
Concessionary power	Concessionary power is the yield of power due to concession conditions. Municipal authorities affected by hydropower development are entitled to buy up to 10 per cent of the power generated. The power bought must not exceed general power consumption within the municipality. The yield from this concessionary power is equivalent to the difference between the price for power in the market and the price for the concession power including the input tax. Some municipalities may choose to sell concession power as full cost to the inhabitants; this gives zero in profits. The concession power price corresponds to generating costs. There are currently two price setting regulations. For licenses issued before 1959, the price is negotiated between the licensee and the municipal authority, limited to a maximum price. For licenses issued after 1959, the price is set by the Ministry of Petroleum and Energy in accordance full costs for a representative selection of power stations. *Source: Statistics Norway*	1054 (3126)

A.4 Other explanatory variables

Variable	Variable Description	Mean (st.dev)
Population	Total population size in the beginning for the year. *Source: Statistics Norway*	11281 (31220)
Sparsely populated	Share of population that lives in sparsely populated areas. *Source: Statistics Norway*	0.48 (0.26)
Voter turnout	Voter turnout in the local government election, i.e. the number of votes as a percentage of the number of eligible voters. *Source: Statistics Norway*	58.76 (3.70)
Private gross income	Aggreagted private gross income after tax (1000 NOK). *Source: Statistics Norway*	8826 (25158)
Deviation precipitation	Deviation in precipitation from normal values within a municipality (mm). *Source:The Norwegian Meteorological Institute, calculated in ArcGIS*	1166 (256)
Deviation temperature	Deviation in temperature from normal values within a municipality ($°C$). *Source:The Norwegian Meteorological Institute, calculated in ArcGIS*	11.4 (0.58)

A.5 Variables in instrument

Variable	Variable Description	Mean (st.dev)
Hydro Potential	See section 6.1 and Appendiks G	$2.43 \cdot 10^7$ ($6.14 \cdot 10^7$)

B First stage regression

Table 2: First Stage

HydroIncome	(1) OLS	(2) IV	(3) IV/FE	(4) IV/FE[a]
Hydro potential	$3.70{\cdot}10^{8***}$	$3.31{\cdot}10^{8***}$	$3.74{\cdot}10^{8}$ ***	$3.74\text{e}{\cdot}10^{8***}$
	(0.000)	(0.000)	(0.000)	(0.000)
Income ex. hydro		0.108	-0.505***	-0.505***
		(0.077)	(0.020)	(0.139)
Population		-0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)
popSparShare		-1.349*	0.106	0.106
		(0.616)	(1.060)	(1.203)
Priv. gross income		0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
Voter turnout		0.066	0.042***	0.042***
		(0.036)	(0.010)	(0.012)
Temp.dev.		-0.733*	0.206	0.206
		(0.326)	(0.119)	(0.121)
Precip.dev.		-0.001***	-0.000	-0.000
		(0.000)	(0.000)	(0.000)
Constant	-0.206	3.334	7.061***	7.061*
	(0.138)	(4.749)	(1.698)	(3.314)
R-squared	0.349	0.397		
N	2569	2569	2569	2569
F	7.165292	8.002504	93.32489	8.535823
Year dummies	YES	YES	YES	YES
Clustered st.errors	YES	YES	NO	YES
Estimation period	2001-2007	2001-2007	2001-2007	2001-2007

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Using the Stata command *xtivreg2*, which is an extensions to Stata's official xtivreg. *xtivreg2* allow clustered st.errors.

C Robustness

Table 3: Robustness regressions

	$80 \leq Eff. \leq 100$		HydroRevenue<5		HydroRevenue> 0		Pop<10,000		Incl. *Eff._1*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Efficiency	FE	IV/FE[a]	FE	IV/FE[a]	FE	IV/FE[a]	FE	IV/FE[a]	FE	IV/FE[a]
Hydro income	-1.113***	-1.020	-1.618***	-1.044	-0.810***	-0.926	-0.989***	-1.393**	-0.950***	-0.438
	(0.199)	(0.651)	(0.389)	(1.784)	(0.114)	(0.645)	(0.137)	(0.448)	(0.142)	(0.562)
Income ex. hydro	-0.989***	-0.974***	-1.204***	-1.181***	-0.820***	-0.903	-1.008***	-1.246***	-1.134***	-0.921***
	(0.165)	(0.146)	(0.162)	(0.142)	(0.155)	(0.479)	(0.150)	(0.282)	(0.154)	(0.259)
Population	0.001*	0.001	0.001**	0.001	0.001	0.001	-0.009	-0.010	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.007)	(0.005)	(0.001)	(0.001)
popSparShare	-3.610	-3.684	-1.320	-1.560	-2.663	-2.752	-5.171	-5.493	4.169	4.651
	(5.692)	(4.605)	(6.274)	(5.019)	(11.579)	(7.461)	(6.339)	(5.420)	(6.874)	(6.161)
Priv. gross income	-0.001*	-0.001	-0.002**	-0.002	-0.001	-0.001	0.009	0.009	-0.002*	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.008)	(0.006)	(0.001)	(0.001)
Voter turnout	-0.155***	-0.157***	-0.104*	-0.109*	-0.178**	-0.169*	-0.161**	-0.146*	-0.153***	-0.162***
	(0.043)	(0.042)	(0.044)	(0.047)	(0.059)	(0.080)	(0.052)	(0.058)	(0.041)	(0.046)
Temp.dev.	-1.598**	-1.604**	-1.941**	-1.982***	-1.616	-1.588	-1.556*	-1.423*	-2.596***	-2.615***
	(0.575)	(0.512)	(0.617)	(0.570)	(0.981)	(0.869)	(0.749)	(0.693)	(0.640)	(0.581)
Precip.dev.	-0.002**	-0.002***	-0.003***	-0.003***	-0.001	-0.001	-0.003***	-0.003***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
E_1									0.269***	0.283***
									(0.031)	(0.029)
Constant	154.018***	153.807***	160.252***	160.306***	145.005***	146.676***	167.751***	173.644***	142.454***	139.258***
	(8.001)	(7.434)	(8.882)	(8.013)	(15.862)	(16.401)	(14.460)	(13.840)	(10.192)	(12.302)
N	2345	2345	2456	2456	1108	1108	1913	1913	2036	2036
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Clustered st.errors	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] All first stage regressions are available on request. The F-statistics in the first-stage regressions vary from 7 to 12 when clustering at municipality level. Also, all results hold when applying clustered standard errors with the unofficial Stata command *xtivreg2*.

D Hydopower production

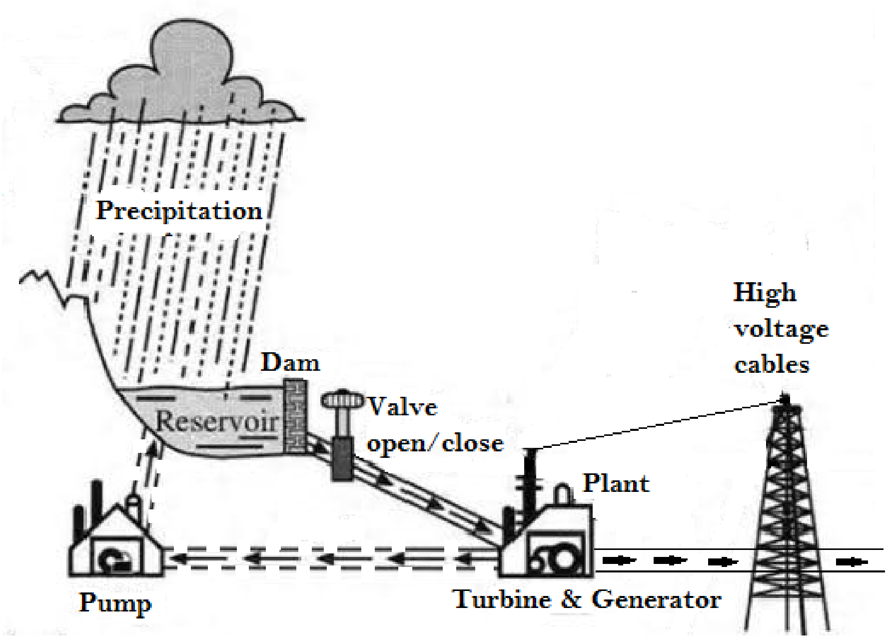


Figure 4: Generation of hydro-electricity by a high-head power plant

E Hydropower income distribution between local governments

Table 4: Income distribution between municipalities

<table>
<tr><td>Variable</td><td>License</td><td>Municipality</td><td>Distribution</td></tr>
<tr><td rowspan="5">Concession power</td><td rowspan="2">Acquire license</td><td>Waterfall</td><td>97 %</td></tr>
<tr><td>Power plant</td><td>3 %</td></tr>
<tr><td rowspan="3">Regulatory license</td><td>Reservoir</td><td>48.5 %</td></tr>
<tr><td>Waterfall and Transfer</td><td>48.5 %</td></tr>
<tr><td>Power plant</td><td>3 %</td></tr>
<tr><td>Natural resource tax</td><td colspan="3">Redistributed to the municipalities that are affected by the water power development and regulation. The more affected the local government is the greater share of the tax they receive.The rules for this distribution is given in The Taxation Act §18-7.</td></tr>
<tr><td>Property tax</td><td colspan="3">Similar to the natural resource tax redistribution. Rules are given in The Act on Property Tax to the Municipalities § 8A.</td></tr>
</table>

F Income equalization program at local level

The income equalization program for the municipalities involves income from income- and capital taxations, and natural recourse tax from the hydropower sector. The purpose of the program is to partly level differences in tax income between municipalities with low tax income and municipalities with high tax income. Municipalities with tax income per capita under the average level will receive a fixed share of the difference between actual tax income and average tax income as compensation. Municipalities with a higher level of tax income than average will be deducted a similar fixed share of the difference between actual tax income and average tax income. This is called a symmetric income equalization program, and has been used since 2005. The fixed rate of compensation and deduction was equal to 55% from 2005 to 2008. In 2009 this rate equaled 57%, as shown in figure 5.

In addition, municipalities with tax income under 90% of average receives an additional compensation of 35 % of the difference between actual tax income and 90% of average level. This compensation is funded by a deduction of a fixed amount per capita from all municipalities. The income equalization program is shown in figure 5.

The equalization program was similar before 2005, but with other redistribution rates. In 2001 municipalities with tax income under 110 % of average tax income received a 90% compensation of this difference. Municipalities with tax income over 140% of average, deducted 50% of the tax income above this level. In 2002 the upper level was set to 138%, in 2003 the upper level was 136%, and in 2004 it equaled 134%. All other details similar as in 2005. By this it follows that municipalities with high tax income experienced a substantial increased deduction of tax income through the equalization program after 2005 (less natural resource tax left after 2005 for municipalities with income above average).

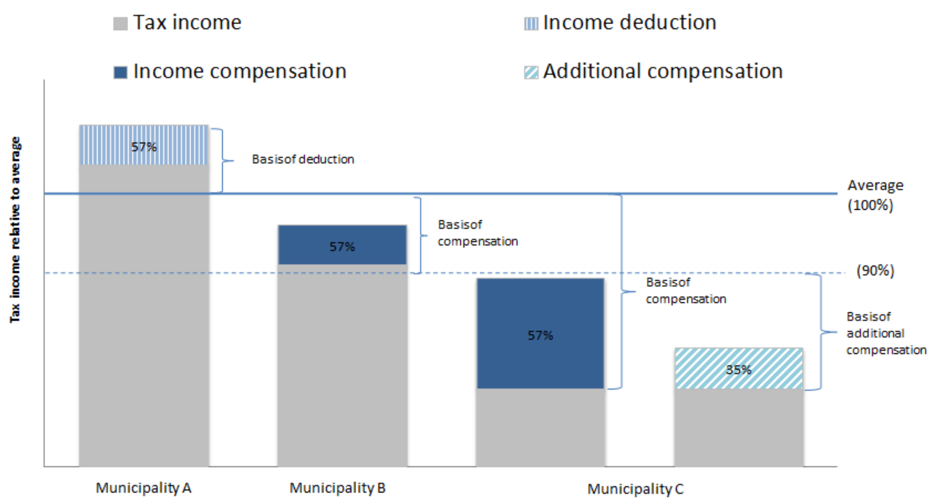


Figure 5: The income equalization program for 2009

G Variables in instrument

G.1 Precipitation

Precipitation data is collected from Norwegian Meteorological Institute. The data consists of 1x1 km. gridded monthly and annual precipitations values. We also have a 1x1 km. gridded dataset of normal (average) precipitation over the period 1961-1990. The gridded datasets are established by a spatial interpolation method. The methodology is reported in Hanssen-Bauer et al. (2006). There is some uncertainty in this data, but on average it will give a good picture on how much precipitation there is at a location.

We have transformed these data using ArcGIS 10 [21]. We calculate the average precipitation value within each local government. The average precipitation for all neighboring municipalities is also calculated for each local government. A visual map is shown in figure 6. The highlighted area show Vinje local government (the center local government in this example) and its neighbors.

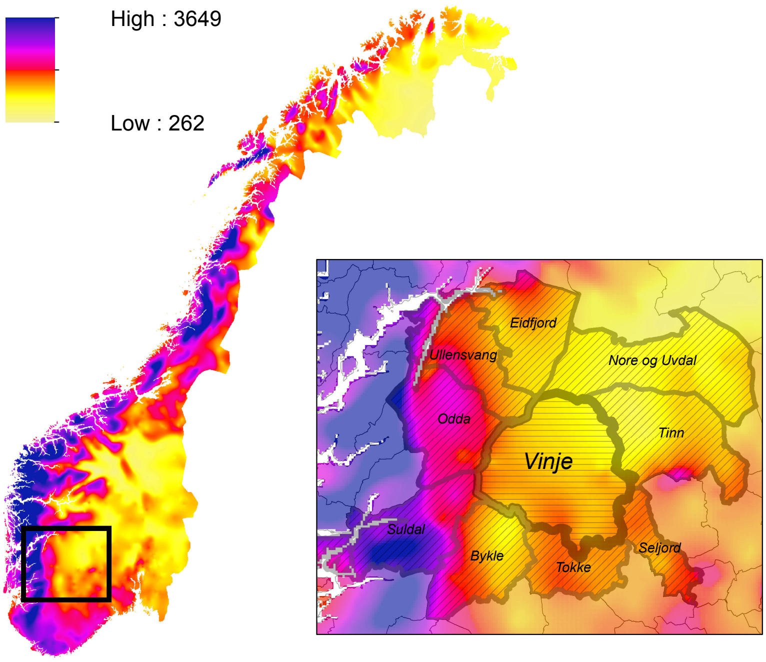
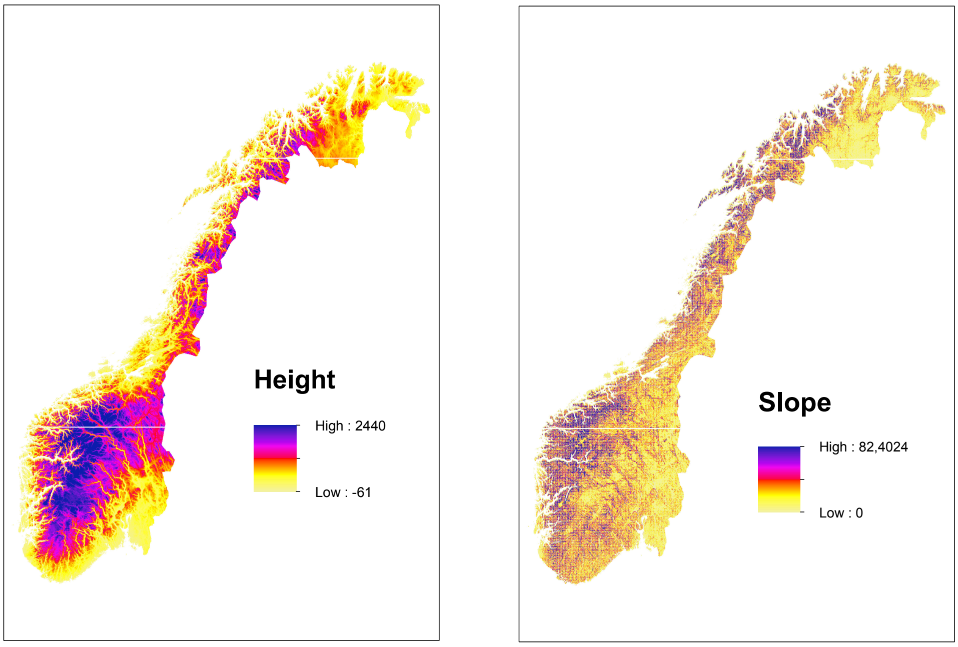


Figure 6: Average precipitation (mm.) in Norway, year 2001

[21] ArcGIS is a suite consisting of a group of geographic information system (GIS) software products produced by Esri.

G.2 Gradient data

The gradient data is calculated in ArcGIS using a terrain model collected from Norway Digital [22]. The terrain model consists of 50x50 meter grids and has a standard deviation equal to ± 4 to 6 meter for its heights values [23]. Once you have a good terrain model it is easy to calculate the average gradient within each grid. Figure 7 shows the terrain model of Norway, and the corresponding slope map. Both maps consist of 50x50 meter grids.



(a) Terrain model

(b) Slope

Figure 7: Terrain and slope map of Norway

[22] Norway Digital - the national geographical infrastructure. See:
$http://www.statkart.no/Norge_digitalt/Engelsk/About_Norway_Digital/$.

[23] Information about the terrain model is given by the Norwegian Mapping Authorities, see:
$http://www.statkart.no/statkart.ny.no/nor/Land/Kart_og_produkter/Terrengmodell/50_meters_grid/Terrengmodell + med + 50 + meters + grid.d25 - SwtLY27.ips$.

G.3 River data

River data is collected from the Norwegian Water Resources and Energy Directorate (NVE). The data reports all rivers (with water run-of above 1 m^3/s) in Norway naturally generated from lakes and rivers. NVE has coupled this data with water run-of variation and in turn classified the water run-of for all the rivers [24]. The rivers are classified into 10 groups given their run-off volume, as shown in figure 8. Like with the precipitation and gradient data there will be some degree of uncertainty in the data.

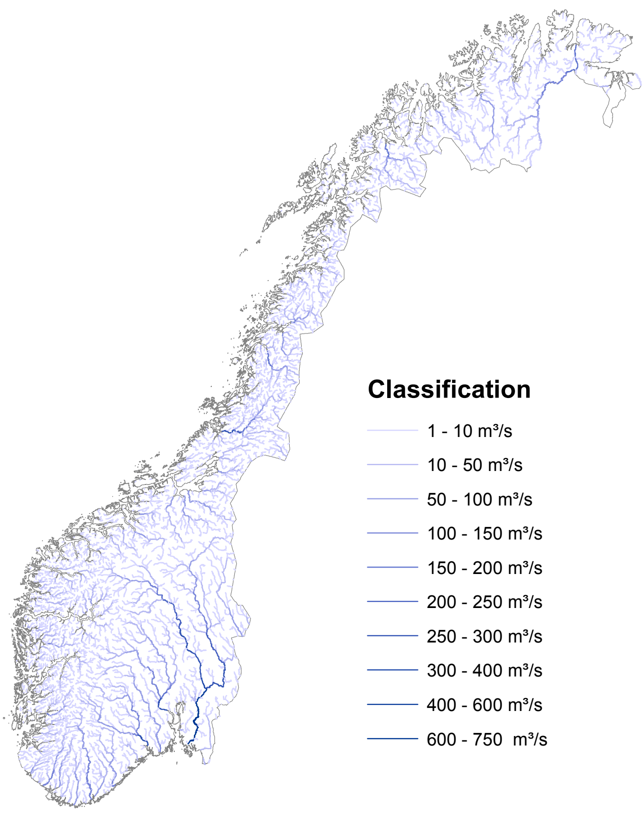


Figure 8: River network classification. Run-off in m^3/s in the period 1960-1991

We have then calculated how many meters river each local government have. This is also been done separately for all classifications. The average meter of river is also calculated for all neighboring municipalities for each local government.

[24]Their water run-of calculations is reported in Beldring et al. (2002). Unfortunately, this report is available only in Norwegian

Meters of river at locations with a slope above 12.8 degrees

As a final calculation in ArcGIS we calculated how many meter of river each local government has in areas with a slope above 12.8 degrees. This is done by coupling the gradient data with river data. Figure 9 shows an example with Bykle local government, the local government with most hydro power income per capita. Bykle has 267.5 km. of river, in witch 90 km. are in areas with slope above 12.8 degrees.

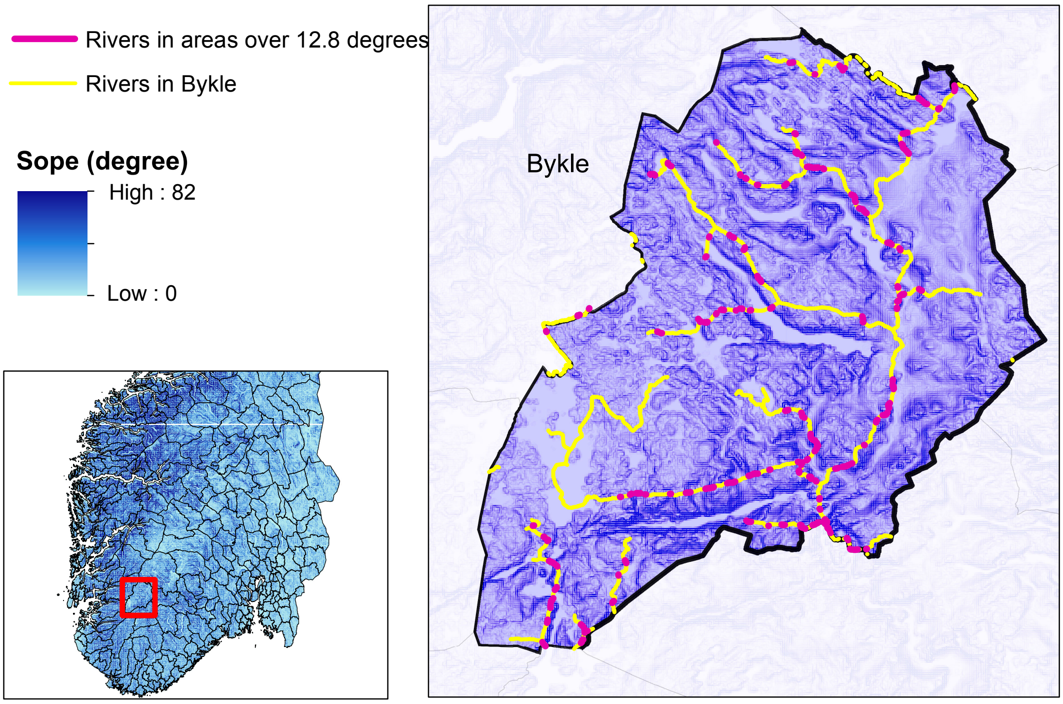


Figure 9: Rivers in Bykle local government: Rivers (above 1 m^3/s) in areas with slope above 12.8 degrees.