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An impact evaluation of Programa de Apoio à Economia Local (PAEL) on the water services provided by municipalities in Portugal

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An impact evaluation of Programa de Apoio à Economia Local (PAEL) on the water services provided by municipalities in Portugal[1]

This Work Project evaluates the impact of the arrears program «Local Economy Support Program» (PAEL), on the water services provided by Portuguese municipalities. The municipalities entering PAEL had to accept a number of commitments, including increasing taxes and tariffs. Hence, we want to analyze how this affects the water services provided by municipalities. We find statistical evidence that PAEL was associated with an increase in water quality, in a range of values for an increase in water quality of 0.373 to 0.663 (in absolute terms), from an already high average water quality above 98%.

Keywords; Policy evaluation, Treatment effects, Programa de Apoio à Economia Local (PAEL)

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1. Introduction

This Work Project performs an impact evaluation of PAEL; «Programa de Apoio à Economia Local» (or the Local Economy Support Program) on the water services in the municipalities in Portugal. PAEL is aimed at reducing debt in the municipalities, regularizing debt payments and improving fiscal discipline in general. One of the obligations that the municipalities in the program had to oblige to was to determine the tariffs in the water services according to the recommendations of ERSAR, the water and waste services regulation authority in Portugal. ERSAR produces different quality indicators for the water services in municipalities, and some of these will be used as indicators for the evolution in the quality of these services. By using different estimation methods, we find statistical evidence that Program 1 of PAEL increased the water quality in the affected municipalities.

The water and waste sector in Portugal has been through a rapid transformation in the last decades, after a new public policy with a program of reforms was defined in 1993. The new policy included various components, and among them was the definition of new tariff and tax policies. In 1993, 81% of the dwellings in mainland Portugal were covered by the public water supply service, while in 2014 it had increased to 95%. In 1993 only 50% of the dwellings in mainland Portugal were provided with safe water (as defined by national and European legislation). In 2014 the corresponding share of safe water was above 98 percent (Baptista 2014). ERSAR 2012 operates with 99-100% safe water as a reference value for good service quality, 97.50-99% as average quality and any value below this as unsatisfactory.

The paper is organized as follows; section 2 describes PAEL and the intuition behind the program, in addition to the organization of the water sector in Portugal. Section 3 presents the data, section 4 describes the methodology and section 5-9 introduces the different estimation methods and the corresponding results, while section 10 contains the conclusion.

2. PAEL: Programa de Apoio à Economia Local

The arrears program PAEL was approved in August/September 2012 (Law 43/2012, 28 August; Portaria 281-A/2012, 14 September). The Portuguese government implemented the program as one of several specific measures to improve fiscal discipline in local and regional governments, and the program is expected to stimulate the local economy by increasing the liquidity of local suppliers (European Commission 2014). The program included a credit line of €1 billion to the municipalities, enabling eligible municipalities to establish medium/long-term loan agreements with the state, to be used to pay municipal debts overdue more than 90 days and short term debt. The loan agreements had to be approved by the respective municipal assemblies and submitted to *Tribunal de Contas*[2] for approval (European Commission 2012).

PAEL was divided into two financing programs, depending on the financial situation the municipalities were in; Program 1 or Program 2. Program 1 includes municipalities that were covered by a financial rebalancing plan and were in a situation of structural imbalance at December 31, 2011. The municipalities in Program 2 had a temporary financial imbalance (Carvalho et al. 2014). In the last week of 2012 six of the municipalities received a first parcel of the payment from PAEL (Silva and Buček 2016). In 2013, 90 of the municipalities in the program received the first parcel of support (PLMJ, 2012). As of 2015 there were 103 municipalities in PAEL. Prior to entry in the program, the municipalities had to present a financial adjustment plan, which contained a set of specified and quantified measures showing how the restoration of the financial situation will happen. The municipalities falling under Program 2 had to present a simplified adjustment program. The adjustment plan should take into account the following; 1) reduction and rationalization of current and capital expenditure; 2) existence of internal control regulations; 3) optimization of own revenue; 4) intensification

[2] *Tribunal de Contas:* The Court of Audtiors in Portugal is the «supreme body which examines the legality of public expenditure and rules on the accounts which the law has ordered to be submitted to the Court».

of the financial adjustment in the municipality the first five years of PAEL (Carvalho et al. 2016).

PAEL involves a number of commitments for the municipalities subject to it. These commitments are monitored during the execution of the contract, and the municipalities in Program 1 will have to accept tougher commitments than the municipalities in Program 2. These conditions include raising fees and tax rates to the maximum (e.g. IMI)[3]. If the municipalities fail to comply with the obligations they have to agree on, they may be subject to sanctions, for instance in the form of reduced transfers from PAEL, as the loans are released in several installments (European Commission 2012). One of the obligations that the municipalities in program 1 were subject to, was aimed at increasing the cost recovery rate in the sector of sanitation, water and waste, in order to make the services self-sustainable in the future. The obligations are defined mainly in paragraph 2 and 3 of article 6 in Law No. 43/2012 of 28 August. Article 6 paragraph 2 states that the municipalities in program 1 of PAEL must comply with the following: *"Determine the prices (tariffs) charged by the municipality in the sanitation, water and waste sectors, in accordance with the recommendations of The Water and Waste Services Regulation Authority in Portugal (ERSAR)"*.

2.1. Tariff guidelines and the new tariff policy

The aim of this project is to evaluate how the obligation of following ERSAR's tariffs recommendations, affected the quality of the water services provided by municipalities in Portugal. A part of the program of reforms introduced in 1993 was a new tariff policy for public water and waste services, aiming at promoting a gradual trend towards cost recovery, so that the services can be self sustainable. Historically, tariffs have been low, and Portugal has sought

[3] IMI is « Imposto Municipal sobre Imóveis», which is a municipal tax on real estate in Portugal. The municipalities itself sets the tax, within in a predefined range.

to evolve from low tariffs to the gradual full cost recovery. The aim is for the water and waste services end-user tariffs should allow for a growing recovery of economic and financial costs accruing from the provision of services (ERSAR 2015). ERSAR produces quality indicators every year, including an indicator named «Coverage of total costs» for the different services, which represents the ratio between total income and gains and total costs.

In 2012 neither the average monthly drinking water supply service tariffs nor cost recovery levels differed much among regions. The tariff guidelines on tariff formation for end-users produced by ERSAR in 2009, states that the tariffs for water and waste services must comply with the principles established by the Environmental Act, the Water Act, the Economic and Financial Framework for Water Resources, the General Framework for Waste Resources and the Local Finances Law, and respect these principles:

1. Cost recovery principle[4], meaning that water and waste services should allow an increasing recovery of economic and financial costs of their provision, in order to ensure the quality of service and the operator's sustainability and based in an efficiency scenario in order not to unduly penalize end-users with costs resulting from an inefficient system management;
2. Sustainable use of water resources principle, meaning that the water services tariffs should contribute to the sustainable management of water resources through the growing internalization of costs and benefits of their use, penalizing waste and high consumption;
3. Affordability principle, meaning that tariffs should allow for the financial capacity of end-users, to the extent necessary to guarantee a trend towards universal access to water and waste services;
4. Principle of user's interests' protection, meaning that tariffs should ensure the proper protection of end-users, avoiding possible dominant position abuses by the operator with regard to service continuity, quality and costs for end-users on one hand, and with regard

[4] In Table 3 in the Appendix, there is additional information on the cost recovery principle.

to their supervision and control mechanisms, on the other hand. These mechanisms become essential under monopoly situations;

5. The elaboration of the tariffs should avoid cross-subsidization practices among different services and activities provided by the operators, which occurs when the economic outcome generated by one or more activities is used to determine another's price.

Thus, it is likely to believe the aim of increasing the cost recovery rate, would increase the municipalities revenue, and therefore it could increase the overall quality of the services provided by the municipalities. Tariffs associated with water sales usually represent the greater part of a utility's revenue, and the lack of adequate revenues can prevent water systems from providing safe, reliable and high-quality water (Water Research Foundation).

2.2. The organization of the water and waste sector

The water and waste sector in Portugal can be divided into two sub-sectors; the water services sub-sector and the municipal waste sub-sector. The water sector is divided into two services within the scope of basic sanitation, providing drinking water supply and wastewater management. This analysis will focus on the drinking water supply[5]. The drinking water supply retail service is in most cases provided by the municipalities or through municipalized services, which account for 79% of the existing 260 operators. *The supply of drinking water* includes the abstraction, treatment, elevation, transport, storage and distribution of water (ERSAR 2015). The responsibility for the water services is divided between the state and the municipalities in Portugal. The activities in the water services sub-sector has been classified as bulk and retail, and the state is responsible for the bulk services and the municipalities for the retail services. The operator (whether state or municipality) can choose between three different management

[5] A broader description of what the drinking water supply services includes is in found in table 2 in the Appendix.

models: direct management, delegation and concession. It is also a possibility to arrange public-public or public-private partnerships in the water sector.

To define whether the water services in a municipality was affected by the municipality entering PAEL, we need to identify the management model of the municipality. If the municipality uses a direct management model, this implies that the municipality itself is responsible for running the water system (ERSAR, 2015). Private concessions are not affected by the PAEL measure. When these concessions are assigned, the tariffs and the regulation of the values in coming years are established in the beginning of the concessions.

There are also two municipalities in PAEL where municipal companies are providing the water services. These are Vizela and Vila Real de Santo António. Anyhow, the municipal company of Vizela does not run the water system, and will not be included in this analysis. The water supply services in Vila Real de Santo António are served by the municipal company VRSA (Sociedade de Gestão Urbana). Since Vila Real de Santo António is the only municipality in mainland Portugal that entered program 1 of PAEL, that is served by a municipal company, this municipality will be treated as a member of the control group. The reasoning behind this is that the local finances law states that all municipal companies that are not financially sustainable, should be shut down. Thus, it should not be likely that the existing municipal companies are in financial trouble, even though the municipal companies' budgets consolidate with the municipalities accounts.

2.3. Municipalities in Program 1 of PAEL

Program 1 of PAEL concerns municipalities that were covered by a financial rebalancing plan and that were in a situation of structural imbalance on December 31, 2011. Following are the municipalities in mainland Portugal in Program 1 where the municipality is responsible for running the water system, with the year of entry in parentheses:

Albufeira (2013), Alfândega da Fé (2013), Alijó (2014), Ansião (2013), Borba (2013), Espinho (2013), Évora (2013), Freixo de Espada à Cinta (2013), Moimenta da Beira (2013), Mourão (2013), Nelas (2013) and Seia (2013) (Carvalho et al. 2014).

3. Data

3.1. Data collection

For this analysis, several water supply quality indicators, as defined by ERSAR, will be used as variables to indicate the quality of the service. The data is collected from the municipalities and companies providing water and waste services yearly from 2011 to 2015, by the Water and Waste Service Regulation Authority (ERSAR) in Portugal. The dataset is a short unbalanced panel dataset; from 2011 to 2015, including 292 companies/municipalities.

3.2. Quality indicators

The following indicators will be used[6], as defined by ERSAR in the *«Water and waste service quality assessment guide»*:

1) Economic accessibility of the service (%): This indicator is designed to assess the adequacy of the user integration, in terms of accessibility of the service, with regards to the economic capacity of households to pay for the service provided by the operator. It is defined as the weight of the average burden with the water supply service in the average disposable income per household in the system's intervention area. An increase in this indicator would imply less affordable services.

2) Water Quality (%): This indicator is designed to assess the adequacy of the user integration in terms of the quality of the service provided, with regard to the quality of water supplied by

[6] For a more detailed on the calculations of indicators, see table 1 in the Appendix.

the operator. It is defined as the percentage of tests carried out from among those required and that complied with the parametric values.

3) Coverage of total costs: This indicator is intended to assess the level of sustainability of the service management in economic and financial terms, with regard to the company's ability to generate its own forms of covering the costs arising from its activity. It is defined as the ratio between the total income and gains and the total spending.

4) Rehabilitation of pipes (%/year): This indicator is designed to assess the level of sustainability of the service management in terms of infrastructure, with regard to the ongoing rehabilitation of pipes to ensure their gradual renovation and an acceptable average age of the network. It is defined as the average annual percentage of abduction and distribution pipes more than ten years old that were rehabilitated in the last five years.

DESCRIPTIVE STATISTICS			
VARIABLES	Mean	Std. Dev.	Min./Max.
Water Quality (*1368**)	98.67	1.58	87.57/100
Economic accessibility (*1365*)	0.44	0.16	0.08/0.98
Coverage of total costs (*1204*)	0.90	0.44	0.1/7
Rehabilitation of pipes (*1074)*	1.07	3.40	0/96.97

** The numbers in brackets denotes the number of observations*

Table 1: Descriptive statistics of the quality indicators

3.3. Variables

Variable name in Stata	Description	Number of observations
companies	All municipalities and companies that runs the water system in Portugal. All «companies» are assigned a number, in order to avoid string variables.	1383
year	The year of the observation. From 2011-2015.	1383
cover	Quality indicator as defined by ERSAR: Coverage of total costs.	1204

access	Quality indicator as defined by ERSAR: Economic accessibility of the service.	1365
quality	Quality indicator as defined by ERSAR: Water quality.	1368
rehab	Quality indicator as defined by ERSAR: Rehabilitation of pipes (%/year).	1074
dmanage	A binary dummy variable = 1 if the water services is runned by the «direct management model», =0 otherwise.	1369
Dt	A binary dummy variable constructed to define if company *i* is treated in year *t*. =1 if treated, =0 if not. The companies in the control group will always be =0.	1383
treatment	A binary dummy variable constructed to define whether company *i* is treated in any point of time *t*. =1 for all years if the company belongs to the treatment group, =0 if the company belongs to the control group.	1383
size	A dummy variable constructed to measure the size of the municipalities. Size =1 if the municipality has less than 20000 inhabitants, =2 if the municipality has between 20000 and 100000 inhabitants and =3 if the municipality has more than 100000 inhabitants. The variable is only created for companies (municipalities) that are managed by the «direct management model», because other companies can run the water system for more than one municipality, and thus it cannot be classified with a certain size as the other municipalities.	926
year2011/2012/ 2013/2014/2015	A dummy variable that is =1 if the observation is in year x, =0 if not.	1383 of each year

Table 2: List of variables used in the analysis

4. Methodology

This project will focus on a quantitative ex post analysis, based on data that was gathered before, during and after the implementation of PAEL. The ex post policy impact evaluation measures the actual impact, but may not be able to capture other mechanisms that affects the outcome. Several estimation methods will be used to estimate the effect on the municipality water services, of being in Program 1 of PAEL, starting with a description of the difference-in-difference approach, that will be applied to fixed and random effects models in section 5 and 6.

4.1. Difference-in-difference

To evaluate the effect of a policy, one of the most frequently used evaluation methods is the difference-in-difference (DiD) estimation framework. In essence, the difference-in-difference estimation is a linear regression that is used in policy analysis, when we want to analyze the effect of a treatment, the treatment in this case being Program 1 of PAEL. In order to use this estimation method, the population must be divided into two groups; a treatment group and a control group. In this case, the treatment group is the 12 municipalities that are directly responsible for running the water system and were in program 1 of PAEL. We know that the treatment is not random, but based on the financial situation the municipality is in. The control group will be all the other municipalities that were either not in program 1 of PAEL or were in PAEL, but do not run the water system itself. A binary dummy variable, D_{it}, indicates the treatment of company *i* in period *t.* For the control group this variable will always be equal to 0. For a company *i* that received the first parcel of financial support from PAEL in 2013, $D_{i2013} = 1$ and the same in the following years.

This analysis does not follow the standard difference-in-difference method, as the treatment does not arise at the same time for all the municipalities. All municipalities receive the treatment in 2013, except one, that receives the treatment in 2014. The difference-in-difference method compares the changes in outcomes over several points in time, between the treatment group and the control group, and the difference is calculated between the observed mean outcomes for the treatment and the control groups, before and after the program was implemented (Khandker, Koolwal and Samad 2010).

The main assumption of the DiD estimation method is the «Common trend assumption». This assumption states that if the treated population had not been subjected to the treatment, both subpopulations would would have experienced the same trends (Lechner 2011). As stated in Gertler et al. (2006), if the outcome trends are different for the treatment and the control group, the estimated treatment effect can be either invalid or biased. It is not possible to prove the common trend assumption of natural causes, since only one of the outcomes will be observed. However, if the outcome time trends are similar before the program was implemented, this will support the assumption. The process of the difference in difference analysis can be presented in a box (table 3), to give a simple overview of the process. β, the treatment effect, is estimated by using the means of the treatment and control group, before and after the treatment.

Company	**Average outcome before**	**Average outcome after**	**Differences:**
Treatment group	Y_{0i1}	Y_{1i2}	$\Delta Y_{i1}=Y_{1i2}-Y_{1i1}$
Control group	Y_{0i1}	Y_{0i2}	$\Delta Y_{i0}=Y_{0i2}-Y_{0i2}$
Difference			$\beta=\Delta Y_{i1}-\Delta Y_{i0}$

Table 3: A simple overview of the difference-in-difference analysis

4.2. Development in quality indicators

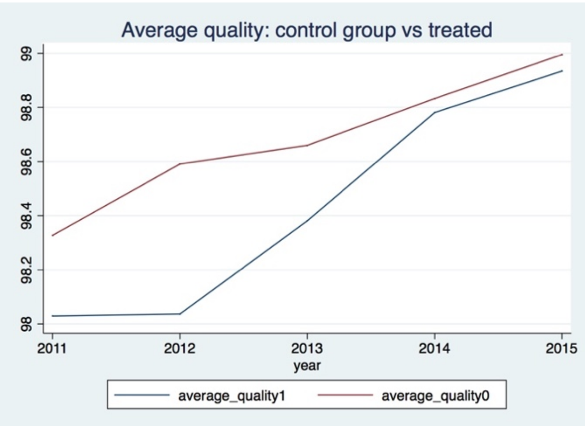
As presented in graphs 1-4, the control group is at a higher level in 2011 for all the quality indicators, compared to the treatment group. With the development over time, especially after 2013 (the implementation of PAEL for all but one municipality), the two groups' averages tend to converge, and for two indicators the treatment group is at a higher average level in 2015. It is important to notice that a high level of economic accessibility implies less affordable services.

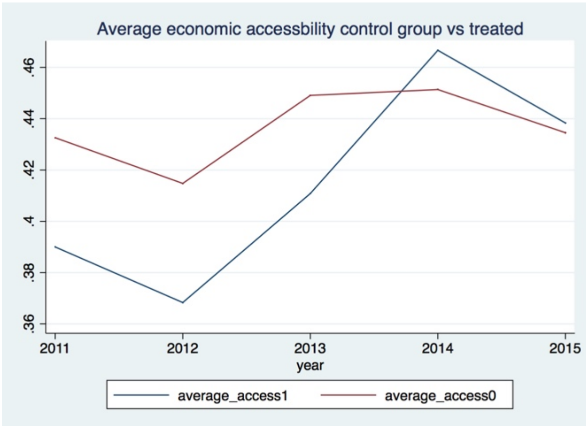
4.3. Equal trend assumption

11 of the municipalities in the treatment group received their first parcel of payment from the PAEL program in 2013, and the last municipality received the first parcel in 2014. The data available is from 2011 until 2015, thus it includes years both prior to and after the treatment occurred, and can be used to analyze the equality of pre-intervention trends. In this case the

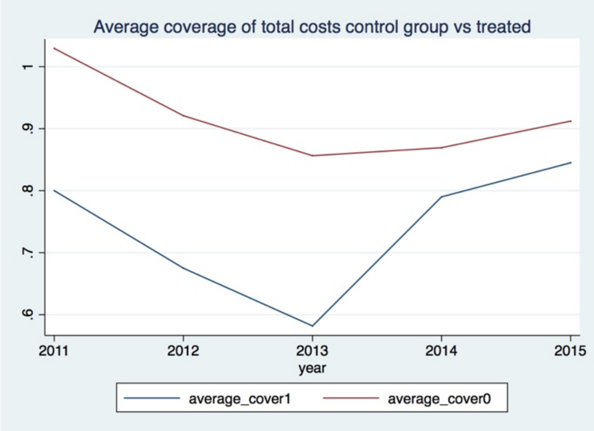
common trend assumption would be; before the municipalities enter the treatment, the municipalities in the treatment group follow the same trend in the quality indicators, as the control group. As shown in graph 1, 2 and 3, the average of the variable «Economic accessibility», «Coverage of total costs» and «Water Quality» seems to move in somewhat similar trends for the two groups until 2013. That is not the case for the variable «Average rehabilitation of pipes», that is moving in different trends (graph 4). This last variable is not used in the estimation in the Difference-in-Difference framework, as it does not comply with the «common trend» requirement. In order to test for the equal trend assumption, we estimate:

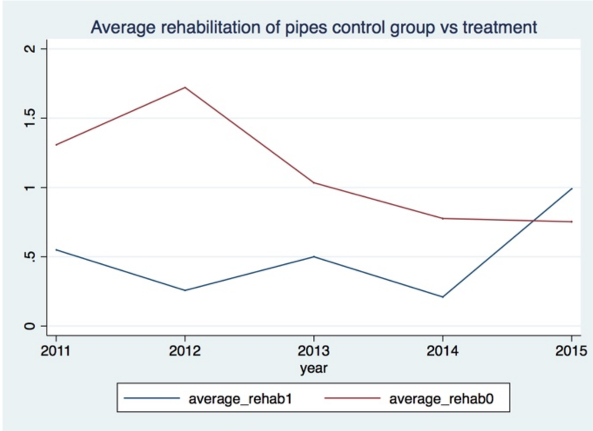
$Y_{it}=\lambda_0+\lambda_1 tD_{it}+\varepsilon_{it}$, where Y_{it} is the dependent variable that we want to test if has similar time trends for the two groups. The independent variable is time (year). The independent variable is assigned numerical values, the first year is =1, the second=2, and so forth. D_{it}=1 if the observation belongs to the treatment group, and D_{it}=0 otherwise. According to the common trend assumption the two groups should have equal trends before the policy is implemented, thus, if λ_1 is similar for the two groups, this will support the assumption of the common trend.





Graph 1: The development of the average water quality in the control group (red) and the treatment group (blue). Graph 2: The development of the average economic accessibility of the service in the control group (red) and the treatment group (blue).





Graph 3: The development of the average coverage of total costs in the control group (red) and the treatment group (blue). Graph 4: The development of the average rehabilitation of pipes in the control group (red) and the treatment group (blue).

DESCRIPTIVE STATISTICS VARIABLES	Treatment Group Mean	Control Group Mean	Std. Dev. Treatment/ Control
Water Quality*	98.43	98.68	0.38/0.23
Water Quality 2011	98.03	98.33	2.32/1.77
Water Quality 2012	98.04	98.59	1.91/1.72
Water Quality 2013	98.38	98.66	1.47/1.52
Water Quality 2014	98.78	98.83	1.29/1.49
Water Quality 2015	98.93	98.99	0.54/1.27

**The average water quality for 2011-2015*

Table 4: Descriptive statistics of the average quality for the treatment and control group.

The water quality was already at a high level in 2011, and thus it is clear that a possible increase caused by the implementation of PAEL, can not be very large before it reaches the highest possible value of 100%. As graph 1-4 exhibits, the gaps between the average of the quality indicators for the treatment and control group are all smaller in 2015, than before the treatment occurred, and the averages tend to converge after 2013.

5. Fixed effects model

Fixed-effects models are used to analyze the impact of variables that differ over time, and requires repeated observations from the same individuals. The fixed-effects model explores the relationship between the independent and the dependent variables within an individual, in this case the individuals being municipalities. The municipalities can have their own characteristics that might influence the dependent variable. We assume that something within the individuals might influence either the independent or the dependent variable, that we need to control for. The fixed-effects model controls for this correlation, and removes the effect of these characteristics, to make it possible to estimate the net effect that the independent variables have on the dependent variable. Another assumption of the fixed-effects model is that the time-invariant characteristics are unique to the individual, and not correlated with the other individuals' characteristics. If a correlation between the error terms is found, a fixed-effects model is not applicable. To check for this, we will run the Hausman test in section 7, to test a random effects model against a fixed effects model (Torres-Reyna, 2007).

The fixed effects regression: $Y_{it}=\beta_1 X_{it}+\alpha_i+u_{it}$, where

- α_i (i=1,…,n) is the unknown intercept for each individual (*n* entity-specific intercepts);
- Y_{it} is the dependent variable, where *i=individual* and *t=time;*
- X_{it} represents one independent variable and β_1 is the coefficient for that variable;
- u_{it} is the individual error term.

A fixed effects model with the dependent variable being water quality, estimates the effect of being in program 1 of PAEL to have a positive effect; an increase of 0.613 in water quality, at a 5% significance level, which corresponds to an increase of 0,63% from the average water quality in the treatment group, before the treatment. By adding one covariate (model 2 table 5) the effect is still significant at a 10% significance level, but adding more than one covariate (model 3) or yearly dummies (model 4) provides estimates with no statistically significant results.

VARIABLES	(1)	(2)	(3)	(4)
Treatment	0.613**	0.592*	0.528	0.332
	(0.270)	(0.338)	(0.344)	(0.337)
Coverage of total costs		0.0538	0.0573	0.0692
		(0.113)	(0.113)	(0.111)
Economic accessibility			0.858	
			(0.837)	
Constant	98.65***	98.71***	98.34***	98.35***
	(0.0286)	(0.106)	(0.380)	(0.133)
Observations	1,368	1,204	1,201	1,204
R-squared	0.005	0.004	0.005	0.051
Nr of companies	292	291	291	291
Yearly dummies	no	no	no	yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Fixed effects models

In addition to the significant result Program 1 of PAEL has on water quality, we also obtain an increase in the quality indicator Economics Accessibility of the service, as a result of the implementation of PAEL. We estimate an increase of 0,059 in the economic accessibility of the service, from an average of 0.44 in the treatment group before the treatment, that implies that the water services are less affordable after the treatment[7].

6. Random-effects model

In the random effects models, the variation across the individuals is assumed to be random, and not correlated with the independent variables in the model, in all time periods (the past, current and future time periods of the same individual). If the individual effects are correlated with other variables in the model, the random effect model is not consistent. Thus, it

[7] The output table for how PAEL affected the economic accessibility is in Appendix, table 9.

is necessary to specify the individual characteristics that might impact the independent variables. Some variables may not be available and therefore lead to omitted variable bias in the model (Torres-Reyna, 2007).

The random effects model: $Y_{it}=\beta_1 X_{it}+\alpha+u_{it}+\varepsilon_{it}$, where;

- Y_{it} is the dependent variable, where *i=individual* and *t=time.*
- u_{it} is the between-individual error and ε_{it} is the within-individual error.
- X_{it} represents one independent variable and β_1 is the coefficient for that variable
- α_i (i=1,…,n) is the unknown intercept for each individual (*n* entity-specific intercepts)

Using a random effects model checking only the effect of being in program 1 of PAEL on the dependent variable water quality, estimates an increase of 0,463 in the water quality, at a significance level of 10 percent (model 1, table 6). By adding one or two more covariates to the model and using robust standard errors in the regression to control for heteroskedasticity (model 2 and 3, table 6), we obtain a positive treatment effect, an increase of 0.371 and 0.373 in water quality, at a significance level of 5%. Thus, adding covariates increases the significance of the treatment variable. This may be because the regression of water quality against only the treatment does not decrease the variation in water quality around its mean sufficiently, and the treatment effect is only significant at a 10 percent level. If the variation in water quality is more associated with a second or third variable, adding these might also change the estimation of the treatment effect and its significance level, as it does in this context. Adding yearly dummies (model 4, table 6) provides no statistically significant result for a treatment effect.

The Breusch-Pagan Lagrange Multiplier test helps deciding between a random effects regression and a simple OLS regression. The null hypothesis is that variances across individuals is zero. That is, no significant difference across units. Here we can reject the null and conclude that a random effects model is appropriate (see table 10 in the Appendix). There is evidence of significant differences across the municipalities/companies (Torres-Reyna, 2007).

VARIABLES	(1)	(2)	(3)	(4)
Treatment	0.463*	0.371**	0.373**	0.160
	(0.250)	(0.172)	(0.173)	(0.287)
Coverage of total costs		0.370***	0.371***	0.387***
		(0.0976)	(0.0980)	(0.0979)
Economic accessibility			-0.0506	
			(0.425)	
Constant	98.68***	98.39***	98.42***	98.08***
	(0.0764)	(0.116)	(0.215)	(0.141)
Observations	1,368	1,204	1,201	1,204
Nr. of companies	292	291	291	291
Yearly dummies	no	no	no	yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Random effects models

7. Fixed or random effects?

When choosing between a random effects and a fixed effects estimator the decision depends on how the time-invariant unobservable variables are related to independent variables in the model. The use of «random effects» is usually synonymous with no correlation between the observed explanatory variables and the unobserved effect. Using fixed effects allows for the independent variables to be correlated with the unobserved effect (Wooldridge 2002). If the individual effects are correlated with independent variables in the model, a random effects model is inconsistent. If we are able to ensure that the individual-specific effect is unrelated with the explanatory variables, a random effects model can be used to make inferences to a larger population.

This is usually tested by the Durbin-Wu-Hausman test. In essence, the Hausman test checks whether the individual error terms (u_i) are correlated with the independent variables, and the null hypothesis is that they are not and that the preferred model is a random effects model and the alternative hypothesis is that a fixed effects model is preferred. In this case, both a random effects and a fixed effects model estimates a positive treatment effect of Program 1 of PAEL on water quality. Depending on which regressions we use in the Hausman test, it provides contradicting results. However, running the Hausman test (see table 11-12 in the Appendix) with the fixed effects regressions that provides a statistically significant positive treatment effect (model 1 and 2, table 5) against the random effects regressions (model 1 and 2, table 6), both suggests rejecting H_0 and thus, choosing a fixed effects model.

7.1. Limitations of the Difference-in-Difference Approach

Even when the trends are parallel before the start of the intervention (the start of the treatment), bias in the difference in difference (DiD) estimation may still occur. The logic behind this is that the DiD approach attributes to the treatment any differences in trends between the treatment and control group, that occur from the time the program is implemented. If any other factors affect the trends between the two groups, the estimated effect of the program will be invalid or biased (Gertler et al. 2006). Any factor that affects only the treatment group at the time of the treatment can invalidate or bias the estimate of the treatment effect. The DiD method assumes that no such factor is present, though it is by nature not possible to prove. We can only provide evidence that supports the equal trends assumption, as done in section 4.3.

8. Other estimation methods for treatment effects

There are several different ways to estimate the average treatment effects based on observed data, in addition to the difference in difference estimation. Estimating average treatment effects has become important in the program evaluation literature (Wooldridge 2002). Treatment effects are introduced by using the potential-outcomes framework. Each individual has an outcome with and without the treatment, where only one of the outcomes are observed.

The potential outcome is the outcome that we do not observe. For instance, if we have an individual that did not receive the treatment, we observe Y_0. Hence, the potential outcome is Y_1. The treatment effects approach seeks to provide a solution to this missing-data problem. We assume that the treatment of individual *i* only affects the outcome of individual *i*, which is known as the stable unit treatment value assumption or SUTVA (Wooldridge 2002).

The aim of these estimation methods is, as in the difference-in-difference approach, to estimate the difference in outcome with and without the treatment. Though now we also consider that the covariates then can be related to the potential outcomes and the treatment. Individuals in the treatment group may differ from the individuals in the control group regarding the covariates, and matching can be effective in removing the possible imbalance in covariates between the two groups (Rubin 1973). The potential-outcome mean for treatment level *t* is the mean potential outcome for the treatment *t*, thus we never observe both potential outcomes for an individual *i.* The average treatment effect is the expected treatment effect on a randomly drawn individual from the population, and the average treatment effect for the treated is the average treatment effect among the individuals that actually received the treatment.

8.1. The regression adjustment estimator

The regression adjustment (RA) uses a regression model to predict potential outcomes adjusted for other covariates, and models the outcome to account for nonrandom treatment assignment (Huber and Drukker 2015). The intuition of using the regression adjustment is to remove covariate imbalance between the treatment and the control groups (Stuart and Rubin 2007). The regression adjustment estimator creates predictions of the outcomes that each individual would obtain for each treatment level, independent of the treatment the individual actually received. Averages over all the individuals estimates the potential outcome means for the treatment level. The regression adjustment estimator provides the average amount by which the water quality increased as a result of the municipalities being in program 1 of PAEL. By controlling for two covariates (model 2, table 7) being in PAEL causes the water quality to increase by an average of 0.42, from the average of 98.30 in the control group, at a 5% significance level. By controlling for more covariates (model 1), we estimate an average increase in the water quality of 0,37 at a 10% significance level. We can express the average treatment effect on the treated as a percentage of the mean water quality we would have observed if no municipalities entered PAEL, then we find that being in Program 1 of PAEL increased the water quality by 0,43% at a significance level of 5%.

VARIABLES	(1)	(2)
Treatment	0.370*	0.420**
	(0.200)	(0.203)
Mean water quality in control group	98.58***	98.30***
Observations	556	918
Controlled for >2 covariates	yes	no

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Regression adjustment estimator

9. Matching estimators

Matching estimators are often used to estimate treatment effects with lack of experimental data, and the typical goal is to estimate an average treatment effect (Abadie and Imbens 2011). The idea behind the matching estimators is to match all treated individuals with the most similar non-treated individual, and then measure the average difference in the outcome variable between the treated and non-treated individuals (Khandker, Koolwal and Samad 2010).

The matching method aims at reducing large covariate bias between the treatment group and the control group (Stuart and Rubin 2007). The average of all the estimated individual-level treatment effects are used to estimate the average treatment effect, or the average treatment effect on the treated. Given the matched individuals, the treatment effect is estimated as the difference in outcomes (Imbens & Woolridge 2009).

9.1. Nearest neighbor matching

As there are very few municipalities in program 1 of PAEL (only 12), the nearest neighbor matching (NNM) estimator can give a more accurate estimate than the difference-in-difference approach. The NMM method selects a number of control individuals for each of the treated individuals, and pairs the observation to the closest match(es) in the opposite group (Abadie and Imbens 2011). When using the NMM, we allow an individual in the treatment group to be matched with more than one individual from the control group, to find the optimal match. The nearest neighbor matching for average treatment effects estimates the average treatment effect on the dependent variable, by comparing observation outcomes between the treated group and the control group, and provides an estimate of the counterfactual treatment outcome.

VARIABLES	(1)	(2)
Treatment	0.663**	0.642*
	(0.338)	(0.330)
Observations	556	556
Bias adjusted	no	yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Nearest neighbor matching

By using the variables rehabilitation of pipes, coverage of total costs, economic accessibility of the service and municipality size as matching variables to define the matching control observation(s), the treated individuals are matched with at least one, and maximum three, individuals from the control group (see table 13 and 14 in the Appendix). The nearest-neighbor matching (model 1, table 8) estimates the average treatment effect on the treated to be an increase of 0,663 in the water quality, at a 5% significance level.

Using more than one continuous covariate introduces large-sample bias in the matching, and in this estimation we use three continuous covariates for matching (rehab, cover & access). By using the bias-correlated matching estimator we adjust the difference within the matches for the difference in their covariate values (Abadie et al. 2004). In this case, using the bias-corrected matching estimator (model 2, table 8) only changes the estimated outcome by a small amount, but there is now only evidence of a positive effect at a 10% significance level. Hence, the bias adjustment reduces the significance level, but still estimates a positive treatment effect.

10. Conclusion

After using different estimation methods to see if, and how, Program 1 of PAEL affected the water quality, we find evidence that the program had a positive effect on the water quality in the affected municipalities. The results from the different estimation methods used (table 9), shows positive results, in a range of values for an increase in water quality from 0.373 to 0.663. The estimated increase is small, yet these values need to be assessed in the context of an already high average water quality above 98% in 2011. Hence, it is clear that a possible increase can not be very high before it reaches the highest possible value of 100% water quality. Furthermore, the different methods all estimates similar results, and there is statistical evidence that PAEL was associated with an increase in the water quality in the affected municipalities.

VARIABLES	Random Effects	Fixed Effects	Regression Adjustment	Nearest Neighbor Matching
Treatment	0.373**	0.613**	0.420**	0.642*
	(0.173)	(0.270)	(0.203)	(0.330)
Observations	1,201	1,368	918	556
R-squared		0.005		
Number of companies	291	292		

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: A comparison of the different estimation methods and its' results.

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