Appendix

This appendix includes detailed results for the paper Estimation of Dynamic Water Demand Function: The Case of Istanbul.

Integration Properties of Variables

In the ARDL approach suggested by Pesaran et al. (2001) and Pesaran & Shin (1999) variables are assumed to be either I(0) or I(1). Since many economic variables generally tend to be integrated of order one or zero (although in some cases they may be I(2)) we do not need to pretest for the existence of unit roots. This may be advantageous as the potential mistakes in pretesting for unit roots can be bypassed. However, to rule out the possibility that the variables in the water demand equation may be I(2) we still need to conduct unit root tests.

Table 1: Unit Root Test Results

	Constant					Constant + Trend				
Variable	Lag	ADF	p	PP	p	Lag	ADF	p	PP	p
$LWPC$	10	-0.39	0.91	-2.99	0.04	10	-0.39	0.99	-2.98	0.14
$\Delta LWPC$	9	-12.01	< 0.01	-10.76	< 0.01					
$LPRICE$	0	-2.94	0.07	-2.74	0.07	0	-3.47	0.05	-3.47	0.04
$LIPI$	13	-1.16	0.69	-1.32	0.62	13	-2.76	0.22	-5.72	< 0.01
$\Delta LIPI$	12	-3.05	0.03	-28.73	< 0.01					
$LTEMP$	10	-2.41	0.14	-3.66	0.005	10	-3.1	0.11	-3.48	0.04
$\Delta LTEMP$	9	-13.03	< 0.01	-7.67	< 0.01					
$LPRECIP$	5	-8.01	< 0.01	-9.38	< 0.01	5	-7.98	< 0.01	-9.35	< 0.01
LPE	0	-1.25	0.65	-1.25	0.65	6	-2.97	0.15	-2.29	0.44
ΔLPE	5	-2.85	0.05	-11.52	< 0.01					
LPG	0	-2.46	0.13	-2.45	0.13	0	-2.40	0.38	-2.40	0.38
ΔLPG	0	-10.98	< 0.01	-10.98	< 0.01					

ADF stands for Augmented Dickey-Fuller test statistic, PP stands for Phillips-Perron test statistic.
Lag order is chosen according to Schwarz Bayesian Criterion.
P-values (p) are computed using MacKinnon (1996) approximation.

Table 1 summarizes the Augmented Dickey-Fuller (ADF), and the Phillips-Perron (PP) unit root test statistics for both logarithmic levels and first differences of the variables. The test regressions include both constant, and constant plus linear trend specifications along with p-values. The lag orders were determined using Schwartz' Bayesian Information criterion (with maximum lag order 13). The ADF and the PP test results generally agree with each other. For log water consumption per capita ($LWPC$) series we fail to reject the null of unit root whereas it is rejected for the first differences implying that $LWPC$ is an I(1) variable. On the other hand, the ADF and the PP tests suggest that log real water price series ($LPRICE$) is trend-stationary in levels. Test results also indicate that industrial production index ($LIPI$), temperature ($LTEMP$), real price of electricity (LPE) and price of natural gas (LPG) are I(1), whereas log total precipitation ($LPRECIP$) is I(0). Overall, none of the variables is I(2).

Table 2: Flexible Fourier ADF Unit Root Test Results

	$LWPC$ ($p = 10$)			$LPPRICE$ ($p = 0$)			LIPI (p=2)		
k	ADF	F−test	RSS	ADF	F−test	RSS	ADF	F−test	RSS
1	−1.27	**6.44**	0.096	−4.25	**2.9**	0.043	−4.01	**4.45**	0.346
2	0.12	4.39	0.098	−3.48	0.21	0.046	−2.7	1.39	0.36
3	−0.11	2.15	0.101	−3.67	1.1	0.045	−2.72	0.52	0.365
4	−0.47	1.67	0.102	−3.48	0.28	0.046	−2.16	0.93	0.363
5	−0.23	1.66	0.102	−3.7	1.87	0.044	−2.71	0.3	0.366

	$LTEMP$ ($p = 10$)			$LPRECIP$ ($p = 5$)			LPE ($p = 6$)		
k	ADF	F−test	RSS	ADF	F−test	RSS	ADF	F−test	RSS
1	−3.18	0.37	4.341	−11.4	1.33	5.135	−2.82	1.3	0.071
2	−3.95	**3.52**	4.171	12.01	**5.08**	4.914	−2.67	0.29	0.073
3	−3.16	0.46	4.344	−11.3	0.69	5.175	−2.76	**3.4**	0.068
4	−3.14	0.52	4.333	−11.3	0.71	5.173	−2.87	0.42	0.072
5	−3.38	3.46	4.175	−11.7	3.51	5.001	−2.77	0.66	0.072

	LPG ($p = 0$)			Critical Values %5	
k	ADF	F−test	RSS	ADF	F−test
1	−2.37	0.44	0.198	−4.31	8.88
2	−3.27	3.35	0.188	−4.01	
3	−2.41	1.81	0.193	−3.77	
4	−2.36	0.54	0.197	−3.63	
5	−2.67	**3.95**	0.186	−3.56	

RSS is residual sum of squares. supF statistics are displayed in bold.
supF critical values are as follows: for $T = 200$ 11.7 at 1% level, 8.88 at 5% level, 7.62 at 10%10 level; and for $T = 100$ 12.21 at 1% level, 9.14 at 5% level, 7.78 at 10% level (see (Enders & Lee 2012, Table 1a, p.197)).
Lag order of the dependent variable (p) is given in parentheses next to the variable names.

As is well-known ADF unit root test is less powerful if there are structural breaks and/or regime changes in the series. In this case, if variable is in fact stationary around a broken trend the ADF test tends to accept the incorrect null. There are several alternative unit root testing procedures in case of structural breaks. Some of these tests require assumption on the type and location of the break (e.g., Perron (1989)). Another variant lets the user only choose the type of break and determines break date(s) endogenously (e.g., Lee & Strazicich (2003), Zivot & Andrews (1992)). A more recently suggested approach, on the other hand, does not make any assumptions on the type, number and location of break and therefore provides a more flexible testing framework. In this approach, it is assumed that deterministic component has a nonlinear structure which can be captured by the appropriate number of flexible Fourier components. For example, the flexible Fourier ADF test regression with only a single component can be written as follows (Enders & Lee 2012):

$$\Delta y_t = \rho y_{t-1} + \alpha_0 + \alpha_1 t + \alpha_2 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_3 \cos\left(\frac{2\pi kt}{T}\right) + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + u_t \tag{1}$$

Trigonometric terms in this equation, which is otherwise the usual ADF test regression under $\alpha_2 = 0, \alpha_3 = 0$, provides an easy way to approximate unknown type and number of breaks without resorting to adding dummy variables and/or trend interactions at appropriate dates. The rejection of the null hypothesis $H_0 : \rho = 0$ implies that y_t is stationary around a nonlinear trend. Enders & Lee (2012) show that under the null hypothesis the ADF test statistic (t ratio) has an asymptotic distribution that depends on the number of frequency components k and the number of observations, T. In practice k is usually unknown but it can be determined by estimating all test regressions for all possible k under a maximum value and then choosing the model with the smallest sum of squared residuals (RSS).

Enders & Lee (2012) also suggested a test for the nonlinearity of the deterministic components which can be applied before the flexible Fourier test. They suggested testing $H_0 : \alpha_2 = 0, \alpha_3 = 0$ using the usual F test statistic that has a non-standard distribution under the unit root null. Also, since k is unknown as well, one needs to compute all possible F statistics for each $k < k_{max}$ and use supremum of these (supF). Enders & Lee (2012) provides an approximation of the distribution of *supF* statistic and its critical values. If the *supF* statistic is less than the critical value at a given significance level, one can conduct the usual ADF unit root tests as it implies that the deterministic components are linear.

Table 2 summarizes Flexible Fourier ADF unit root test results with $k_{max} = 5$. For $LWPC$ series the minimum RSS (or maximum F) value occurs at $k = 1$ frequency component. The ADF test statistic is -1.27 which is larger than 5% critical value. The *supF* statistic is 6.44 which is smaller than 5% critical value (8.88). Thus, the null hypothesis of linear deterministic components cannot be rejected. Similarly, the supF statistics indicate that the deterministic components in $LPRICE$ and $LIPI$ series are linear. In fact, the *supF* statistics are all insignificant for all variables in the model. Overall, these results reinforce that the usual ADF unit root test statistics can be safely used.

Further Estimation Results

Table 3 displays detailed ARDL estimation results for the two subsamples described in the main text. Table 4 and Table 5 summarize the ARDL estimation results and long-run elasticity estimates using seasonally adjusted water consumption series, respectively.

Table 3: ARDL Estimation Results in Subsamples

Dependent variable: $\Delta LWPC_t$	2006m12−2010m12 ARDL(1,0)			2011m1−2014m12 ARDL(2,0)		
	Model (1)	Model (2)	Model (3)	Model (1)	Model (2)	Model (3)
$LWPC_{t-1}$	-0.667^{***}	-0.667^{***}	-0.665^{***}	-0.666^{***}	-0.670^{***}	-0.647^{***}
	(0.095)	(0.096)	(0.097)	(0.073)	(0.073)	(0.076)
$\Delta LWPC_{t-1}$				0.367^{***}	0.368^{***}	0.354^{***}
				(0.096)	(0.095)	(0.096)
$LPRICE_t$	-0.213^{**}	-0.190^{**}	-0.194^{**}	0.114	0.358	0.478
	(0.089)	(0.094)	(0.095)	(0.269)	(0.317)	(0.341)
$LIPI_t$	0.165^{***}	0.131^{*}	0.141^{*}	0.088	0.085	0.094
	(0.051)	(0.067)	(0.071)	(0.115)	(0.114)	(0.114)
$LTEMP_t$	0.037^{***}	0.037^{***}	0.037^{***}	0.047^{***}	0.047^{***}	0.043^{***}
	(0.012)	(0.012)	(0.012)	(0.010)	(0.009)	(0.010)
$LPRECIP_t$	-0.012^{***}	-0.011^{***}	-0.011^{***}	-0.011^{***}	-0.010^{***}	-0.010^{***}
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
$trend$	0.001^{**}	0.001^{*}	0.000	0.001	0.000	−0.000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
LPG_t		−0.031	−0.042		0.076	0.306
		(0.040)	(0.046)		(0.054)	(0.246)
LPE_t			0.042			−0.311
			(0.083)			(0.325)
$constant$	-2.009^{***}	-1.852^{***}	-1.827^{***}	-1.962^{***}	-2.191^{***}	-2.675^{***}
	(0.392)	(0.442)	(0.449)	(0.678)	(0.690)	(0.855)
N	49	49	49	48	48	48
AIC	−215.411	−214.129	−212.440	−234.657	−235.047	−234.194
BIC	−202.169	−198.994	−195.414	−219.688	−218.206	−215.482
$\bar{R}^2$	0.577	0.573	0.565	0.718	0.725	0.724
AR (1)	0.051 [0.82]	0.051 [0.82]	0.008 [0.93]	0.967 [0.33]	1.934 [0.16]	1.662 [0.2]
White Noise	0.699 [0.71]	0.632 [0.82]	0.643 [0.8]	0.685 [0.74]	0.750 [0.63]	0.796 [0.55]
RESET	2.104 [0.12]	1.875 [0.15]	1.668 [0.19]	6.542 [0.001]	5.272 [0.004]	4.280 [0.011]
ARCH LM	0.012 [0.91]	0.030 [0.86]	0.032 [0.86]	0.581 [0.45]	0.110 [0.74]	0.013 [0.91]
Normality	0.033 [0.98]	0.338 [0.85]	0.203 [0.90]	3.717 [0.16]	3.059 [0.22]	2.943 [0.23]
VIF	2.447	3.006	9.913	3.463	4.899	48.662

Standard errors in parentheses. P-values are in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: ARDL Estimation Results for Seasonally Adjusted $LWPC_t$ Series

	(1) CENSUS X13	(2) TRAMO-SEATS	(3) Dummy variables
$LWPC_{t-1}$	0.426^{***}	0.424^{***}	0.446^{***}
	(0.080)	(0.078)	(0.078)
$LPRICE_t$	-0.180^{***}	-0.170^{***}	-0.170^{**}
	(0.063)	(0.064)	(0.065)
$LIPI_t$	0.140^{***}	0.138^{***}	0.129^{***}
	(0.033)	(0.034)	(0.034)
$LTEMP_t$	-0.013^{**}	-0.007	-0.010^{**}
	(0.005)	(0.005)	(0.005)
$LPRECIP_t$	-0.007^{***}	-0.009^{***}	-0.009^{***}
	(0.002)	(0.002)	(0.002)
trend	0.001^{***}	0.001^{***}	0.001^{***}
	(0.000)	(0.000)	(0.000)
constant	-1.609^{***}	-1.623^{***}	-0.524^{**}
	(0.272)	(0.275)	(0.203)
N	97	97	97
AIC	-483.772	-478.480	-475.542
BIC	-465.749	-460.457	-457.519
$\bar{R}^2$	0.876	0.871	0.868
AR(1)	0.348 [0.56]	0.761 [0.38]	1.393 [0.24]
White Noise	0.649 [0.79]	0.686 [0.74]	0.781 [0.58]
RESET	1.471 [0.23]	0.656 [0.58]	0.889 [0.45]
Normality	6.003 [0.05]	6.761 [0.03]	4.398 [0.11]
VIF	7.782	7.316	7.318

Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Long Run Elasticity Estimates for Seasonally Adjusted Series

	(1) CENSUS X-13	(2) TRAMO-SEATS	(3) Dummy variables
$LPRICE_t$	-0.313^{***}	-0.296^{***}	-0.306^{***}
	(0.095)	(0.098)	(0.103)
$LIPI_t$	0.243^{***}	0.240^{***}	0.233^{***}
	(0.051)	(0.052)	(0.055)
$LTEMP_t$	-0.022^{**}	-0.011	-0.019^{*}
	(0.008)	(0.009)	(0.009)
$LPRECIP_t$	-0.012^{***}	-0.016^{***}	-0.017^{***}
	(0.004)	(0.004)	(0.004)
Bounds F	11.962	13.922	12.857
Bounds t	−7.189	−7.414	−7.098

Note: This table displays long run elasticity estimates and PSS bounds test results for the ARDL model summarized in Table 4.

References

Enders, W. & Lee, J. (2012), 'The flexible fourier form and dickey-fuller type unit root tests', *Economics Letters* **117**(1), 196 – 199.

Lee, J. & Strazicich, M. C. (2003), 'Minimum lagrange multiplier unit root test with two structural breaks', *Review of Economics and Statistics* **85**(4), 1082–1089.

MacKinnon, J. G. (1996), 'Numerical distribution functions for unit root and cointegration tests', *Journal of Applied Econometrics* **11**(6), 601–618.

Perron, P. (1989), 'The great crash, the oil price shock, and the unit root hypothesis', *Econometrica* **57**(6), 1361–1401.

Pesaran, M. H., Shin, Y. & Smith, R. J. (2001), 'Bounds testing approaches to the analysis of level relationships', *Journal of Applied Econometrics* **16**(3), 289–326.

Pesaran, M. & Shin, Y. (1999), An autoregressive distributed lag modelling approach to cointegration analysis, *in* S. Strom, ed., 'Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium', Cambridge University Press.

Zivot, E. & Andrews, D. (1992), 'Further evidence on the great crash, the oil-price shock and the unit-root hypothesis', *Journal of Business and Economic Statistics* **10**(3), 251–270.