Water Utility Journal 22: 27-42, 2019.

Water demand in Qatar: Future trends and conservation scenarios

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Abstract: We model water consumption in the market segment that compose the Qatari water market. We link water consumption to population growth. Building on the estimated model, we develop long-range forecasts of water consumption from 2018 to 2030 over different scenarios for the population driver. In addition, we proxy for water efficiency improvements by reducing the long-run elasticity of water consumption to population. We show that the efficient use of water has a crucial role in controlling the future evolution of water consumption. Water conservation policies should consider this aspect and we call for the implementation of water efficiency improvement programs.

Key words: Water consumption; water use efficiency; scenario-based forecast

1. INTRODUCTION

Water resources in Qatar are scarce due to very low precipitations, limited aquifer water, and the absence of rivers. Until 1953, the population of Qatar was entirely reliant on groundwater for its potable and agricultural needs. This water, which was brackish in places, was pumped from shallow aquifers in the central and northern areas of the state. Nowadays, most of the fresh water resources in Qatar is desalinated water. The groundwater covers less than 2% of the demand side (mostly due to the limited rainfalls). The state of Qatar built its first desalination plant in 1953, and the country's desalination capacity has been increased over the years. In 2014, almost 100% of water for potable water supply was produced by desalination plants (with a total production of 476 Mm^3 in 2014). To mitigate water stress in Qatar, the government initiated the Water Security Mega Reservoirs Project. The objective of this project is to double the existing water storage by building a new mega reservoir.

With respect to the demand side, Qatar domestic water consumption is among the highest in the world and the highest among the GCC states (Gulf Cooperation Council), as measured by the water consumption per capita peaking at 418 m^3, a level that increases to 600 m^3 if we focus on Qatari only. Unfortunately, the gap between water demand and water availability in Qatar is expected to increase to 141 m^3 in 2020 years (Omara 2016). In the meantime, Qatar's rapidly growing economy and population (mainly due to immigration) are causing a relevant increase in water demand. At the sectoral level, in 2017, the dominant water-consuming sectors in Qatar were the residential (Villa and Flats) and the industrial sectors, which account for 77 percent of the total water consumption, with the remaining 23 percent split between commercial (including hotels) and government sectors. The purpose of this study is to estimate a dynamic model for water consumption at the sectoral level, taking also into account the population dynamic. With the estimated model, we provide a prediction of water demand in Qatar at different scenarios for the population variable and by introducing the possible beneficial effects due to the adoption of water conservation policies.

The estimated model is consistent with the literature in the choice of possible variables driving water consumption. The peculiar structure of the Qatari market makes the variable selection very limited, with the water consumption dynamic and the population evolution being the only relevant elements. Therefore, to develop scenario-based water consumption forecasts, we build on population growth scenarios. These scenarios start in 2018 and end in 2030 to match the QNV2030 program time horizon[1]. We match the population scenarios with the possible effects linked to the adoption of water conservation policies. However, we do not observe variables that monitor or proxy water conservation. Therefore, we proxy for water conservation changes through the elasticity of sectoral water consumption to population. This is coherent with the assumption that an improvement in water conservation is reducing the impact of population growth on water consumption. Such a choice is in line with the recent contribution of Khalifa et al. (2018) within an electricity consumption framework.

In the context of energy policies, this paper aims at measuring the likely economic gains of improved water conservation to encourage the adoption of appropriate water consumption policies in Qatar. Various economic sectors will be investigated in our paper, hence enabling us to devise sector-tailored policies that can lead to positive effects for the economy of Qatar. Pursuing water conservation measures in the housing sector might enhance the standards of residential services and lower impoverishment and social disparity, especially among the most vulnerable families. Water conservation, if endorsed strongly in the Qatari community, will allow Qataris to lower their energy consumption, which will consequently reduce the stress on water resources. This is confirmed by our scenario based evidences where the enhancement of water conservation, as proxied by lowering long-run elasticities of population to water consumption lead to a contraction in long-run water consumption levels. Accordingly, the adoption of water conservation policies can significantly contribute to Qatar's future program of energy conservation.

The paper proceeds as follows. Section 2 provides a literature review, while Section 3 provides detailed description of Qatar's water market and of the data we use in our analyses. Section 4 introduces the econometric methodology, while Section 5 describes the scenarios. Section 6 analyzes the water consumption levels obtained by combining the estimated model with the scenario, and Section 7 concludes and provides policy recommendations.

2. LITERATURE REVIEW

Droughts, population growth and climate change are some of the challenges facing the countries or areas with limited water resources. Traditional research approach has often focused on the supply side to deal with water scarcity. However, recently, substantial amount of research has shifted the attention towards demand side to obtain a more inclusive view of this issue. There are several strands of research investigating the demand side.

The first strand of literature mainly deals with the top-down approach in estimating the water demand. For example, Fan et al. (2017) find that the daily water consumption per capita is affected by several factors, such as water supply capacity and socioeconomic status. An increase in the awareness grew that better water demand forecasts meant a better understanding of the factors creating that demand. Howe and Linaweaver (1967) conducted one of the earliest forecasting studies, later followed by Boland (1997) and Bauman et al. (1998). Over the years, researchers in different fields have successfully proposed diverse theories and techniques to upgrade the water estimation toolkit. These studies can be divided into two main branches. The first, includes contributions from economists who mainly studied the effect of price level and tariff structures on water demand using econometric methods (e.g., Arbués et al. 2003; Dalhuisen et al. 2003; Worthington and Hoffman 2008, among many others), while the second comprises multidisciplinary contributions from civil engineers and modelers (e.g., Donkor et al. 2012). Both lead to remarkable influences on a variety of innovative forecasting tools based on statistical, econometric, neural networks and agent-based models.

When focusing on the estimation approach, water demand models consider that water demand might be altered by modifying pricing policies, but also by implementing water conservation

[1] We adopt this forecast horizon to have a consistency with the national vision of sustainable development and environment protection, as defined in the program QNV2030.

policies such as well-informed awareness campaigns and water device retrofit incentives. Implementation of these policies varies from one country to another, and is not globally diffused, especially in the areas where water is still perceived as an abundant resource (Rinaudo, 2013).

Water demand estimation and forecasting can be done for varying target horizons. For instance, short-term forecasting tools intent to predict water demand for the immediate hours, days or weeks, while factoring in changes in the weather and consumer behavior, with relevant impact for reservoirs and desalination plants management. Intermediate-term forecasting (1-10 year) aims at anticipating water consumption variability by a fixed or slowly increasing customer base (Rinaudo 2015). On the other hand, the long-term forecasting methods focuses on a 20 to 30 years estimation horizon. Policy makers and authorities rely on this timeframe when building long-lifespan water supply infrastructures like desalination plants, storages, or large-capacity inter-basin transfers.

Water utilities adopted a variety of estimation and forecasting tools to anticipate the future evolution of water demand (Billings and Jones 2008). We can summarize these methods into five major categories: temporal extrapolation model (Billings and Clive 2008; Lee et al. 2010; Donkor et al. 2012); unit water demand analysis; multivariate statistical models (Arbués et al. 2003; Dalhuisen et al. 2003; Fullerton and Molina 2010); micro-component modeling (Froukh 2001; Levin et al. 2006) and land use based models. In recent times, composite models, are also gaining wide attention. These are hybrid tools obtained by combining many aforementioned forecasting models. For example, the IWR-MAIN (Institute for Water Resources – Municipal And Industrial Needs) software package is a mix-match of many forecasting models including extrapolation models, statistical models, unit water demand models, and end-use models (Mohamed and Al-Mualla 2010; Environment Agency et al. 2012). Despite attaining significant progress in the last three decades in water forecasting, a number of challenges still exist. In fact, the previously cited approaches still suffer from a few drawbacks, including a proper treatment of uncertainty, the integration of water demand forecasting with urban development planning, and appropriate accounting for climate, economic and demographic changes into the model.

Within the modeling and forecasting framework, the scenario-based approach is among the most widely used methods to address the issue of uncertainty in water demand estimation (Rinaudo 2015). This approach uses a number of contrasting scenarios by accounting for uncertainties attached to probable evolution of water demand in the future. Scenarios are drafted with narrative description of different ways in which society might evolve and use water resources within a given time range. These scenarios are expected to assist water authorities to assess the performance of alternative strategies within various plausible future circumstances. The Environmental Agency in the UK initiated this approach in 2001, with further subsequent developments (Westcott 2004).

The second strand of literature highlights how attitudes, economic incentives and state regulations influence water use. For example, Aprile and Fiorillo (2017), Kang et al. (2017), Willis et al. (2011) and Maas et al. (2017) realize that pollution and resource exhaustion have a positive impact on water consumption. Complementary with the previous studies Wolters (2014) observes that environmental concern about water scarcity and socio-demographic factors cause 9% of the variation in conservation behaviors. Moreover, Salvaggio et al. (2014) find that environmental value orientation, knowledge and concern about water use are all significant predictors of water conservation. With respect to habits and intentions, Jorgensen et al. (2013) find that habit strength, self-reports of past water conservation, and perceived behavioral control were good predictors of the intentions to conserve water. Differently, within field experimental studies, Fielding et al. (2013) and Otaki et al. (2017) note that providing a continuous feedback on water use supported conservation efforts. In addition, Liu et al. (2016) find that providing detailed water-use information appealed to the vast majority of householders, and further supported change in behaviors (e.g., shorter showers and full washing machine loads) and installations of new infrastructure. Furthermore, Binet et al. (2013) conclude that clearer information on marginal prices can lead to lower water use. Some other studies, Mini and Pincetl (2015), Stavenhagen et al. (2018) and Katz et al. (2016) examine how policies might alter consumer's behavior. Their findings show that enforcing more stringent mandatory outdoor watering restrictions, pricing measures, advertisement campaigns and other municipal regulations are effective in reducing water use. However, Hughes (2012) deduces that voluntary programs need to be accompanied by effective enforcement and monitoring. From a different viewpoint, pointing at incentives, Lee et al. (2011) observe that water conservation incentives contribute significantly to water conservation. Within the same strand of behavioral studies, Garcia-Cuerva et al. (2016) find that financial incentives encourage consumers to participate in water reuse programs. Expanding on the previous point, Bernedo et al. (2014) focus on longer-term impacts of nudges (technical information, moral suasion and social comparisons) which were found to be persistently effective tools to reduce water use during a drought. Furthermore, Asci et al. (2017) find that water use was highly responsive to price changes among heavy residential water users. Darbandsari et al. (2017), Nataraj and Hanemann (2011), Wichman (2014), Wichman et al. (2016), Strong and Goemans (2015) note that increasing water price and investment in advertisings can effectively impact water consumption in the studied area. Other factors affect water consumption: Romano et al. (2016) find that climatic and geographic factors (in particular the altitude) have a negative effect on water consumption, while Stoker and Rothfeder (2014) find that the level of water consumption differs across seasons.

With respect to factors related to housing, several studies provide evidence in favor of the impact of home characteristics (infrastructure, number of bathrooms, temperature and efficient appliances) on water consumption; see Strong and Goemans (2015), Matos et al. (2014), De la Cruz et al. (2017), Fox et al. (2009), Willis et al. (2013), Makki et al. (2013, 2015), Rathnayaka et al. (2014), Jorgensen et al. (2009), Lee et al. (2011), among many others.

In the context of agriculture, Grammatikopoulou et al. (2016) find financial variables to be effective only when applied to active farmers and in contrast, passive owners' conservational behavior mainly depends on attitudes. In addition, Dagnino and Ward (2012) demonstrate that farmers are likely to adopt water-saving technologies if they receive subsidies to switch to drip irrigation. Surprisingly, results show that subsidies provided to adopt drip irrigation might raise the demand for water. In the case of Tunisia, Boubaker et al. (2018) find that soil and water conservation technologies (SWCT) were positively correlated to socio-economic and institutional factors such as membership within an agricultural cooperative, while participation in trainings for SWCT and livestock holdings were negatively correlated with adoption.

Building on this literature, we provide a model-based simulation approach accounting for scenarios on the water consumption drivers to produce long-run forecasts of water consumption.

3. QATAR WATER MARKET AND DATA DESCRIPTION

Qatar's state rapidly growing economy and population (the latter grows mainly due to immigration) caused a sensible increase in the water demand. From the offer side, as we already mentioned, water comes almost entirely from desalination plants. These plants are operated by a semi-governmental company and the water distribution is managed by a governmental corporation, the Qatar General Electricity and Water Corporation, KAHRAMAA. In 2015, there were two main desalination plants, Ras Abu Funtas (RAF) and Ras Laffan (RL), with RAF including 5 internal desalination sub-plants, and RL composed by 3 desalination sub-plants. The total distributed potable water was 476.8 Mm^3 in the year 2014 for a population of 2,216,180 capita. Therefore, the gross consumption (including losses) per capita equals 588 liters per day in 2014. Desalinated water is distributed through a network that includes pipelines and storage tanks. Almost all the Qatar population has access to safe drinking water through this distribution network, except very small remote households that are supplied by safe drinking water through registered tankers. In the last decade the water distribution network went through a sensible enlargement, and the number of buildings connected to the network raised from 119,357 in 2010 to 293,681 in 2015, leaving only 3.42% of total buildings not connected to the drinking pipeline network.

With respect to the demand side, the Qatar state faces increasing water consumption because of many factors, including the population growth, the overall increasing number of economic activities and a targeted increase in food production. The increasing need for water and the actual water production, relying on desalination and thus capped in the short term period represent critical challenges for the Qatar government. In fact, the need to fulfill the demand, the high cost and environmental impact of water desalination, must be tackled all together, and will require significant investments. These aspects are supporting our study which will focus on recovering the long-run water needs. Our approach builds on data on water consumption. KAHRAMAA has kindly provided the basic water consumption data we use in our analyses. The data are available at the monthly frequency, starting in January 2008 and ending in June 2017. The time series consists of the water consumption levels in Mm^3 as recovered from a billing database. We had access to data for the total Qatar water consumption as well as for a split among six market segments: two residential segments, Flats and Villa, the Government segment, the Industry segment and two further economically relevant segments, the Hotel and the Commercial. Figure 1 reports the time evolution of water consumption over the segments. It clearly emerges that the series do have different behaviors, with anomalous observations (in particular the Hotel segment), breaks or changes in the behavior (the Commercial segment seems flat for the first part of the sample and then takes a trending pattern while the Industry segment shows a clear increase in the level from 2010 to 2012). Nevertheless, all series seems to be characterized by elements potentially related to a non-stationary behavior either due to deterministic or stochastic components.

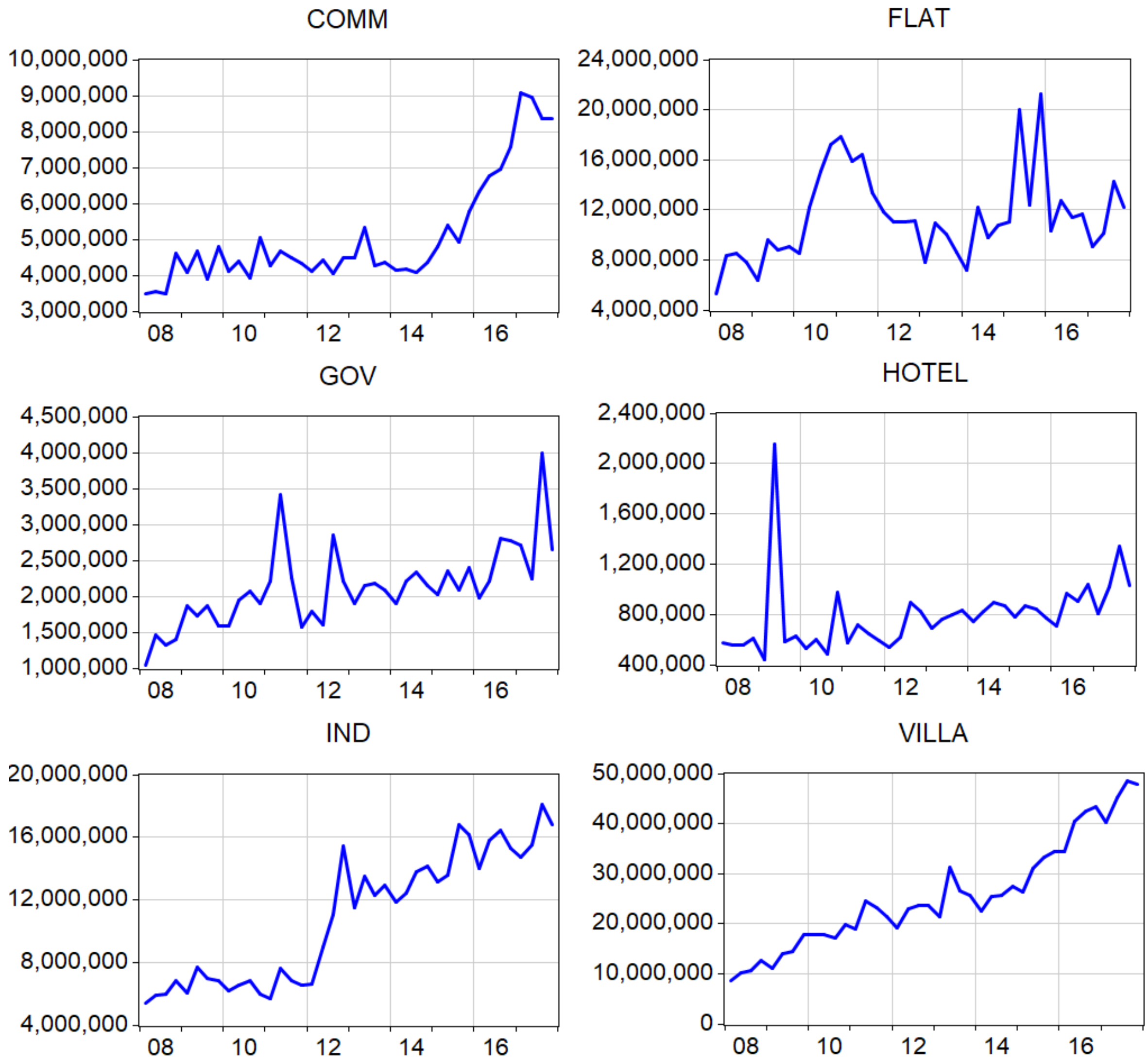

Figure 1. Quarterly time series of water consumption (in Mm^3) obtained by simple sum of monthly figures.

Table 1 reports stationarity tests, accounting for the presence of an intercept and a trend. The tests are not always concordant, as there is evidence in favor as well as against, the presence of unit roots. On the one side, all the three tests indicate stationarity of water consumption log-levels for Flat, Government, Hotel and Villa market segments. For both the ADF and Phillips-Perron tests, the Commercial and Industry water consumption are non-stationary, while the KPSS indicates that also these two market segments have a stationary water consumption log-level. Given these results, and given the small sample size of the time series we analyze, we prefer a conservative approach and, therefore, when we do not have an agreement among tests, we opt for the occurrence of stationarity. We motivate our choice for Commercial and Industry on the basis of the empirical evidence of stationarity for four market segments. These findings rule out the possibility of using error correction model in the estimation.

Table 1. Unit root tests on the water consumption by market segment

	ADF		Phillips-Perron		KPSS	
Segment	Test stat.	P-value	Test stat.	P-value	Test stat.	1% Crit. Val.
Commercial	-0.848	0.952	-2.079	0.540	0.156	
Flat	-3.943	0.019	-3.853	0.024	0.094	
Government	-5.475	0.003	-5.494	0.000	0.144	
Hotel	-7.474	0.000	-8.002	0.000	0.120	0.216
Industry	-2.888	0.177	-2.891	0.177	0.087	
Villa	-3.987	0.017	-3.966	0.018	0.121	
GDP	-2.580	0.290	-2.465	0.344	0.105	
Population	-0.731	0.967	-1.764	0.713	0.305	

Table 1 reports several tests for stationarity of water consumption (in logs) for the various market segments. For the ADF and Phillips-Perron tests, the null hypothesis is the presence of a unit root while for the KPSS test, the null hypothesis is stationarity (rejections for large values of the test statistic).

4. MODELLING STRATEGY

The evidence of stationarity in the water consumption time series around a deterministic trend, challenge the specification of a forecasting model based on scenarios developed for the two relevant drivers previously described, the population and the GDP. In fact, in this situation, a fundamental role will be taken by the deterministic component, and the introduction of conditioning variables, such as Population and GDP, might become difficult given their non-stationarity (around a deterministic component). On the one side, the possibility of using models and specifications based on common stochastic trends, i.e. on the possible cointegration between the drivers and the water consumption, is ruled out, due to the stationarity of water consumption time series. On the other side, if we exclude the drivers from the model, and specify a time series model for water consumption levels based only on water consumption data, we will not have any conditioning information on which we could draw future scenarios. In fact, the future evolution of water consumption time series might be driven by the trend and a linear or non-linear component that drive the fluctuations around a trend. In the latter case, scenarios will be difficult to specify.

However, a further possibility exists. If the water consumption log-levels share the same deterministic pattern of an economic or a demographic driver, we could proxy the deterministic component of the water series by the economic driver time series. While on the one side this preserves the coherence of the modeling strategy, as we account for the deterministic pattern of water consumption, on the other side we are including in the model an economic driver for which we could draw scenarios. This possibility has been investigated, from a methodological point of view, by Bierens (2000) that introduced the concept of co-trending, i.e. the presence of common deterministic components in two, or more, time series, and developed a procedure for testing the presence of co-trending. Similarly to the cointegration case, the co-trending analysis identified the co-trending rank, i.e. the number of common deterministic trends between variables. Consequently, in an analysis involving K variables, the co-trending rank might vary between 0 and K.

In our case, the presence of co-trending could allow specifying models where the drivers are used as explanatory variables for the water consumption levels. In fact, the common deterministic trend will act as a common latent factor leading to a clear significance in the link between the target variable and the explanatory variables. Furthermore, the presence of co-trending will rule out the interpretation of this model as spurious regressions.

Table 2. Co-trending testing between market segments, GDP and Population

Segment	R=1 Test stat.	5% Crit. Val.	R=2 Test stat.	5% Crit. Val.
		Co-trending analysis with Population		
Commercial	0.163	0.465	0.953	0.674
Flat	0.095		0.943	
Government	0.133		1.104	
Hotel	0.094		1.023	
Industry	0.090		0.931	
Villa	0.129		1.014	
		Co-trending analysis with GDP		
Commercial	0.185	0.465	0.984	0.674
Flat	0.073		0.508	
Government	0.156		1.086	
Hotel	0.171		1.050	
Industry	0.163		0.809	
Villa	0.163		1.018	
GDP & POP	0.168	0.465	0.939	0.674

The co-trending rank identifies the number of common deterministic trends. For R=1 the null hypothesis is that of 1 (alternative 0) common deterministic trend, while for R=2, the null is that of two deterministic trends versus an alternative of one. Rejection is for large values of the test statistic.

Therefore, we proceed to the co-trending analysis of Bierens (2000), that allows for detecting the presence of common deterministic trends between series. We run the test between one water consumption series (on one market segment) and one driver, as our final purpose is to develop scenarios for the water consumption in each market segment. The total water consumption will be obtained as a sum of single segment forecasts. According to Bierens (2000), when running the test between a pair of time series, we might have three possible outcomes: no common deterministic trends, i.e. the co-trending rank is zero; one common deterministic trend, i.e. the co-trending rank is equal to one; two common deterministic trends (co-trending rank equal to two). We report results in Table 2.

The co-trending analysis shows interesting results. For the Population case, we observe that for all water market segments, the tests show evidence in favor or co-trending. Therefore, the deterministic pattern that characterize the Population evolution and the deterministic pattern that is present in the water consumption log-levels are the same. Such a finding allows to consider Population as a possible explanatory variable for water consumption. For the GDP we obtain similar results, apart in the Flat case where the water consumption and the GDP seems to be characterized by two different trends. We also analyze the co-trending between the two exogenous variables, identifying the presence of a common deterministic trend. This last finding highlight that a single deterministic component is present in the two variables we plan to use in specifying a dynamic model for water consumption levels.

We then advance to the estimation of a general dynamic model including economic and demographic drivers. Let y_t^i be the log-level water consumption in market segment i, X_t the bivariate vector containing the log-levels of GDP and population, D_t a vector of dummy variables (possibly interacted with lagged values of the dependent or with the contemporaneous or lagged values of elements included in X_t), and ε_t^i an innovation term. We consider the following general model:

$$y_t^i = \alpha + \sum_{j=1}^{p} \beta_j y_{t-j}^i + \sum_{i=0}^{q} \delta_i' X_{t-i} + \gamma' D_t + \sum_{l=0}^{m} \theta_l \varepsilon_{t-l}^i \quad (1)$$

where we allow for an Autoregressive Distributed Lag structure, possibly augmented with dummy variables to capture either specific outliers or structural breaks, and with an error term that could follow a moving average process.

Table 3. Estimated models

	Comm.	Flat	Gov.	Hotel	Ind.	Villa
Intercept	15.082	15.711	13.932	12.853	15.320	15.491
	(0.050)	(0.309)	(0.111)	(0.086)	(0.074)	(0.214)
Population	0.346	0.667	0.869	0.939	0.758	2.122
	(0.086)	(0.451)	(0.171)	(0.119)	(0.127)	(0.333)
Step Dummy 2014 Q3	-3.351					
	(0.275)					
Step Dummy 2012 Q3					0.510	
					(0.042)	
Population x Step Dummy	3.865					
	(0.299)					
Dummy 2009 Q2				1.277		
				(0.156)		
AR(1)		0.574	0.225			0.663
		(0.116)	(0.190)			(0.142)
AR(3)	-0.512					
	(0.172)					
SAR(1)		0.437				0.528
		(0.195)				(0.123)

Table 3 reports estimated coefficients and standard errors (in parentheses) for the various models we fit on the water consumption log-levels across the six market segments (over columns). We include as explanatory variables the Population log-levels, possibly interacted with a step dummy, step and impulse dummies, as well as autoregressive components (at lags 1 and 3) and seasonal autoregressive components (at lag 1 and with a period equal to 4, i.e. one year).

To specify the model, we follow a general-to-specific strategy, keeping the maximum lag order to 4, and evaluating the inclusion of seasonal patterns in the autoregressive component of the model by analyzing the estimated residuals serial correlation. Table 3 reports the final specification adopted for the various market segments.

We first observe that only Population remains in the model and GDP is never selected as a possible explanatory variable due to its low level of significance. We carefully verified this outcome by checking the fit of model specifications where Population was not included from the beginning. The exclusion of Population generates a worse fit and, in general, does not lead to specifications with the inclusion of GDP among the variables of interest.

Population is always highly statistically significant apart in the case of the Flat segment. We prefer to maintain the Population in this case in order to be conservative given the small sample size (34 observations) and given that the introduction of Population results in even worse outcomes. In terms of coefficient size, we first remind that the coefficients, given the log-log specification of the model represent elasticities of water consumption to changes in the population level. The impact of Population on water consumption changes across market segments and is the smallest for the Commercial sector (about 0.35). Four sectors, Flat, Hotel, Government and Industry have an elasticity varying between 0.67 and 0.94, while the Villa segment elasticity jumps to 2.1. The latter finding is somewhat expected given the average water consumption in Qatar. In fact, Qatar domestic water consumption is among the highest in the world, and the highest among the GCC states (Gulf Cooperation Council), peaking at a per-capita level of 418 Mm^3 for the full population and 600 Mm^3 when focusing on Qatari. Notably, at the sector level, the dominating water consumption segments are the residential (Villa and Flats) and the Industrial sectors, as they account for 77% of total water consumption; the remaining 27% is split between commercial (including hotels) and government sectors as the data in 2017 show.

The models include some dynamic elements, which are, however, heterogeneous across market segments: totally absent for Hotel and Industry, limited to simple AR components for Commercial and Hotel, and including seasonal AR components for Flat and Villa. This last evidence might be related to the specificities of these two segments that capture the water consumption for the total residential segment which might be because of the sharp increase in the real estate investment and increasing number of immigration inflow to fill the shortage in labor resources in Qatar.

Finally, the Commercial, Hotel and Industry segments include dummy variables to capture the structural breaks highlighted in the previous section. Note that in one case, the Commercial segment, a step dummy affects both the intercept as well as the impact on the Population role. This leads to a huge change in the elasticity that from the last quarter of 2013 jumps to a value above 4. This result should be taken with care due to the limited sample size (ending in 2017) and will surely have effects on the scenario analyses. We also tried to exclude the interaction term, but this was providing an inferior model fit. A step dummy impact on the model intercept is present in the Industry case, while for Hotel the model includes a dummy capturing an outlier in the second quarter of 2009.

5. THE WATER CONSUMPTION TREND UNDER DIFFERENT POPULATION SCENARIOS

The selected future paths of water consumption are conditional to a set of possible scenarios for its main driver, the Population growth. Beside this aspect, a further element affecting the evolution of the future water consumption is the possible improvement in the water efficiency use. We first consider the role played by the population scenarios and in the following section we discuss the role of efficiency improvement. To recover the scenario-based evolution of water consumption we proceed as follows. We assume the availability of a sample size of T observations, and we also assume we do have a future path for the population. The latter, together with the interaction term, enter all in the vector x_t. We are interested in recovering the future path of water consumption, from time *T+1* to *T+M*, in a given market segment, *i*, which we denote by Y_{T+l}^{i}. The future level comes from the following equations:

$$\widetilde{y_{T+l}^{i}} = \hat{\alpha} + \sum_{j=1}^{p} \widehat{\pi_y} \widetilde{y_{T+l-1}^{i}} + \sum_{i=0}^{q} \widehat{\pi_x'} x_{T+l-1} + \hat{\gamma}' D_{T+l} + \widetilde{\varepsilon_{t-l}^{i}} \qquad (2)$$

$$Y_{T+l}^{i} = \widetilde{Y_{T+l-1}^{i}} e^{\Delta \widetilde{y_{T+l}^{i}}} \qquad (3)$$

where hats denote estimated values (of coefficients) and tilde denote scenario-based forecasts for the variables of interest (with the usual convention that if *T+l-j<T+1* we do not have forecasts, but observed values).

We consider five different scenarios for Population evolution, all with similar patterns but differing in terms of the growth level. All the population scenarios start with five years of larger population growth compared to the reduced growth in the following eight years. The baseline scenario for population growth, Scenario 0, mimics the population growth forecasts of the Internal Strategic Planning Forum of the State of Qatar, which predicts a population growth of about 5% until 2022 and growth at the 3% rate from 2023 to 2030. The other four scenarios we consider simply modify the baseline scenario by scaling up or down the growth rates of the baseline scenario. We decrease by 1% (scenario 1) or increase by 1% (scenario 2) the population growth in the years 2017-2022, and increase (scenario 1) or decrease (scenario 2) by 0.5% the growth in the years 2023-2030. Scenarios 3 (scenario 4) uses a decrease (increase) of 2% and 1% in the first five years and in the following eight years, respectively.

We now consider the design of scenarios for the water conservation level. In our models, we do not have an economic driver that monitors water conservation. Therefore, changes in efficiency will not be proxied by a change in a reference variable. Differently, we assume that changes in water conservation impact on the elasticities, i.e. on the coefficients included in π_x' in equation 1, given that the model includes variables in log-levels. In fact, those coefficients represent the impact of the population changes on the water consumption changes. Increases in water conservation will lead to a smaller impact of population growth on the water conservation. In this case, we associate scenarios with a percentage decrease in the elasticity. Therefore, we consider the baseline scenario, where water conservation is not affected, and three scenarios associated with a 1%, 5% or 10% decrease in the elasticity. Such a choice is clearly limited and does account for possible heterogeneity in the improvement of water conservation across the different market segments. Within our simulation framework, as the changes in water conservation are not immediate, that is they do not lead to an immediate decrease in elasticities, we assume that the decrease in the elasticities is distributed over years. For the first scenario, we allow for a decrease in elasticity at a rate of 0.2% per year for 5 years. Similarly, in the second case, we consider a decrease in elasticity at a rate of 1% for 5 years, and in the third case, a decrease in elasticity at a rate of 1% for 10 years. In all cases, the decrease of the multipliers will start in 2019, as water conservation improvements need some time to produce effects on the water consumption.

Table 4 reports the increase in water consumption, conditional to the various scenarios for population, in each market segment. The increase is striking, and unrealistic, in the Commercial sector, but this a consequence of the pattern of water consumption in this segment in the last years. We tried different alternative specifications for the Commercial water consumption model, but without obtaining a reasonable solution that was solving this behavior. For the remaining sectors, we note different patterns in the Villa segment and in the Flat segments, the two residential sectors.

Table 4. Increase in yearly water consumption compared to the consumption in 2017

	S0	S1	S2	S3	S4	S0	S1	S2	S3	S4
	COMM					FLAT				
2020	72%	53%	91%	35%	111%	23%	20%	25%	18%	28%
2025	268%	187%	363%	119%	472%	40%	34%	47%	29%	53%
2030	587%	380%	855%	226%	1195%	55%	46%	65%	37%	75%
	GOV					HOTEL				
2020	4%	1%	7%	-1%	10%	6%	3%	9%	-1%	12%
2025	22%	15%	29%	8%	37%	25%	18%	33%	10%	42%
2030	39%	28%	51%	17%	63%	44%	31%	57%	20%	72%
	IND					VILLA				
2020	10%	7%	12%	4%	15%	32%	25%	40%	17%	48%
2025	27%	20%	33%	14%	40%	93%	68%	120%	46%	150%
2030	42%	32%	53%	22%	65%	163%	116%	219%	77%	284%

Table 4 reports the scenario-based increase in water consumption in each market segment for the five cases described in this Section. The table measures the increase at the yearly level (cumulated quarterly water consumption in each year) compared to the total water consumption observed in 2017, and without any improvement in energy efficiency. The table reports a comparison on selected years.

While the former show, under the baseline scenario, an increase of 65%, the latter peaks at 219%. Clearly, the level of water consumption in the Villa segment will represent a crucial aspect to monitor from a policy perspective. Differently, the Industry, Government and Hotel segments show increases similar to the Flat case, from 51% to 57%. By moving away from the baseline scenario, the consumption levels maintain similar patterns, in relative terms, and this is a consequence of the existence of similar patterns in the competing population scenarios. However, we highlight that, with a contraction in Population growth, the benefit would be higher for Industry, Hotel and Government compared to the Flat case, the increase in the former is more than halved, while in the latter we move from 65% to 37%. Finally, in the Villa case, we see a relevant drop, from 219% down to an increase of, only 77%.

By focusing on the total level of water consumption, we note the crucial role of the Villa segment, see Figure 2: the total consumption moves from about 330 Mm^3 up to around 900 Mm^3, about half of them associated with the Villa segment. In relative terms across segments, see Figure

3, we note that the fraction of water consumption coming from the Villa segment is almost constant, while the other changes are due to the unrealistic growth in the Commercial segment.

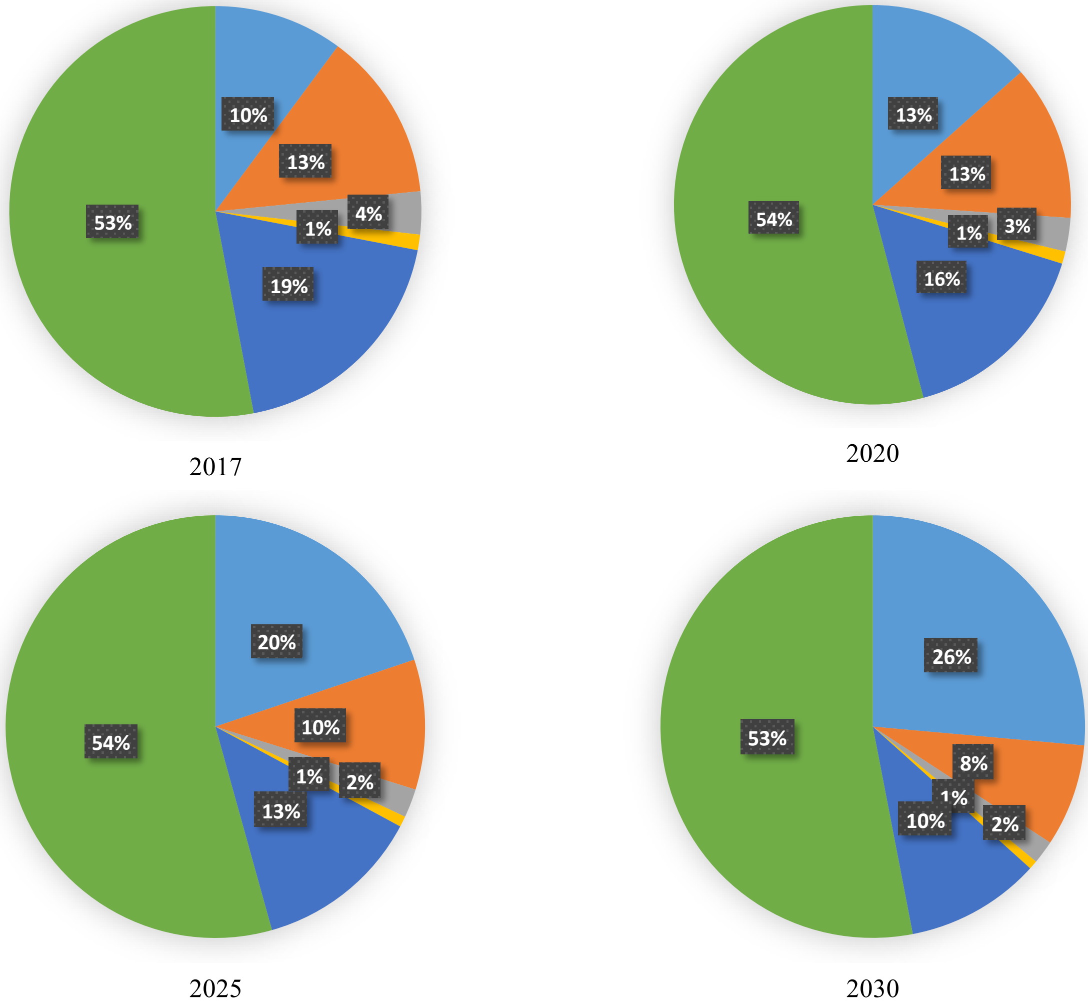

Figure 2. Composition of total water consumption in Qatar in the baseline year (2017) and in 2020, 2025 and 2030, under the baseline scenario (S0). Clockwise, the market segments: Commercial (light blue), Flat (orange), Government (gray), Hotel (yellow), Industry (blue), and Villa (green).

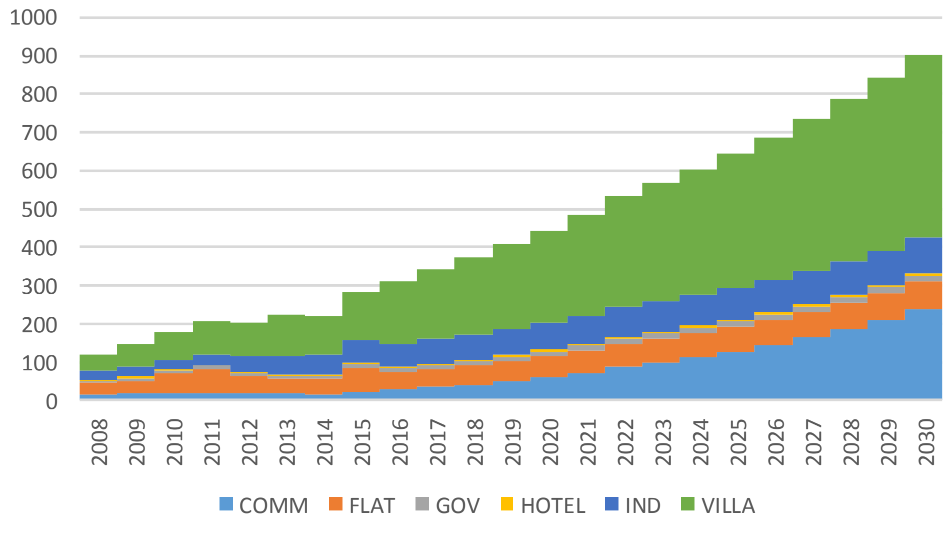

Figure 3. Total yearly water consumption in Qatar split by market segment from 2008 to 2030. Real data up to 2017, baseline scenario from 2018 up to 2030 (left scale in Mm^3).

6. WATER NEEDS AND WATER CONSERVATION

When comparing water consumption in GCC countries with Europe's domestic water consumption, we observe that GCC countries generally consume more water than Europe. For instance, the average per capita domestic water consumption in Qatar, UAE, Bahrain and Saudi Arabia is around 269 liters per day compared with the 169 liters (on average) in Italy, Spain, France, UK, Germany and Austria. This means that the GCC domestic water consumption per capita is 38 percent higher than that of these European countries, a significant difference. Among the GCC states, Qatar's water consumption is the highest, peaking at an alarming level of 418 liters per capita per day. This figure is 39 percent greater than the second highest water-consuming GCC country, and 36 percent higher than the GCC average. This aspect, coupled with the infrastructure of water production and distribution in Qatar and with the increasing trends in water consumption, as highlighted by the previous section, call for the need of policy choices by the Qatar government. While the supply side requires infrastructural projects, already planned, the demand side would require the adoption of policies pointing at the Qatari habits, in particular for the adoption of water conservation practices.

To provide an evaluation of the potential impact on water consumption of this last aspect, we run two different simulations. In the first case, we analyze the long-run effect of a 1% (5%) decrease in the elasticity water consumption to changes in the population. The implicit assumption we make is that the adoption of water conservation policies reduces the elasticity. We measure the long-run effect as the percentage decrease in consumption compared to the values observed in 2017. Table 5 reports the results. We first note the odd pattern of the Flat segment. This is due to the peculiar behavior of the segment in the last years, leading, in the long-run and under the adoption of water conservation policies, to an increase in water consumption compared to the 2017 level. However, we highlight that in 2017 the Flat segment water consumption reported a level of 45.6 Mm^3, while the yearly average for the range 2008-2017 is 45.9 Mm^3, and the maximum yearly level was that of 2015 with 64.6 Mm^3. Therefore, the increase of up to 14% of water consumption would provide a value within the historical range of consumption levels for this specific market segment.

Differently, for the other market segments, we note how water conservation policies, as proxied by a contraction of water elasticity to population, would lead to sensible decreases in water consumption levels. The most evident contraction is that of the Commercial segment, that with a drop of elasticity of 5% provides a contraction in demand of about 18%. The least reactive segment is the Industrial one, with a decrease of 4.4%, while Government, Hotel and Villa, show a water demand decrease of more than 9% with a contraction in elasticity of 5%. These results are promising and show that water conservation policies could have a crucial role in controlling the evolving water demand in Qatar. However, these elements must be coupled with the scenarios on the population evolution.

Table 5. Long-run contraction of water consumption

	1%	5%
COMM	-2.59%	-17.86%
FLAT	13.86%	10.83%
GOV	-7.28%	-9.50%
HOTEL	`-5.67%	-9.23%
IND	-1.28%	-4.40%
VILLA	-1.45%	-9.56%

Table 5 reports the contraction (on a yearly basis) of water consumption conditional to a decrease in the elasticity to population by 1% (second column) or 5% (third column). We measure the contraction under the long-run consumption levels coherent with the end of 2017 population level (i.e. assuming a zero-growth rate for population and let the water consumption converge to the steady state).

We thus run a second simulation that focuses on the water conservation scenarios when combined with the baseline population scenario. In the baseline scenario, i.e. the baseline population scenario, we do not have adoptions of water conservation policies. The three scenarios for water conservations are those described in Section 5. We label the water conservation scenarios as E-2, E-3 and E-4, while we also refer to baseline scenario as water conservation scenario E-1.

Table 6. Change in water consumption with conservation improvements

		Change w.r.t. Case 1			Change w.r.t. 2017			
		E-2	E-3	E-4	E-1	E-2	E-3	E-4
COMM	2020	-2.50%	-11.87%	-11.87%	71.31%	67.03%	50.97%	50.97%
	2025	-5.40%	-24.23%	-34.53%	267.62%	247.78%	178.56%	140.69%
	2030	-5.98%	-26.55%	-46.05%	584.99%	544.00%	403.14%	269.56%
FLAT	2020	-0.40%	-1.97%	-1.97%	24.48%	23.99%	22.03%	22.03%
	2025	-0.87%	-4.30%	-6.48%	40.50%	39.27%	34.46%	31.39%
	2030	-0.97%	-4.77%	-9.31%	55.05%	53.54%	47.66%	40.62%
GOV	2020	-0.52%	-2.57%	-2.57%	4.16%	3.62%	1.48%	1.48%
	2025	-1.14%	-5.57%	-8.37%	21.96%	20.57%	15.17%	11.76%
	2030	-1.27%	-6.17%	-11.96%	38.69%	36.93%	30.13%	22.10%
HOTEL	2020	-0.56%	-2.77%	-2.77%	5.64%	5.04%	2.71%	2.71%
	2025	-1.23%	-6.00%	-9.00%	25.26%	23.72%	17.75%	13.98%
	2030	-1.37%	-6.65%	-12.85%	43.90%	41.94%	34.34%	25.41%
IND	2020	-0.47%	-2.34%	-2.34%	9.74%	9.23%	7.18%	7.18%
	2025	-1.04%	-5.08%	-7.65%	26.70%	25.39%	20.26%	17.01%
	2030	-1.15%	-5.63%	-10.95%	42.42%	40.78%	34.40%	26.83%
VILLA	2020	-1.26%	-6.15%	-6.15%	30.93%	29.28%	22.87%	22.87%
	2025	-2.76%	-13.04%	-19.21%	92.42%	87.11%	67.32%	55.45%
	2030	-3.06%	-14.40%	-26.72%	163.29%	155.23%	125.38%	92.93%

Table 6 reports the change in water consumption, on a yearly basis, with respect to reference periods. All simulations consider the baseline population scenario, E-1, and the possible scenarios associated with the adoption of water conservation policies. In columns 3 to 5, we report changes with respect to the yearly consumption under scenario E-1, i.e., in the absence of conservation improvements. In columns 6 to 9, we report changes with respect to the consumption in 2017.

Table 6 reports the evaluation of water conservation improvements by comparing the contraction to both E-1 (the scenario without water conservation policies), as well as to the water consumption observed in 2017. We start from the latter element, and comment on the evolution of the water consumption, compared to 2017, when we adopt water conservation policies. The Commercial segment is somewhat unrealistic, as noted in the previous section. However, we point out that the adoption of strong water conservation policies, as those associated with scenario E-4 (a 10% drop in the elasticity of water consumption to population), the water consumption prediction is halved in 2030 compared to the case without water conservation policies. The effects are clearly more evident in the long run than in a few years. For the Flat segment, the adoption of water conservation policies provides limited effects, for the same motivations associated with the odd result in Table 5.

Results for the other segments show a similar behavior, with a significant contraction in water consumption, more evident in the long-run, and increasing with the strength of the water conservation policies effects. If we focus on 2030 and we compare the case without water conservation policies to the case with the stronger effects of water conservation policies, we note that in the Government sector the water consumption, under the baseline population scenario, increases by 38.7% (compared to 2017 levels) in the first case, and only by 22.1% in the second case. For the Hotel sector, the drop is even stronger, from an increase of 43.9% down to a value of 25.4%. Industry is similar to Hotel, with figures equal to 42.4% and 26.8%. Villa is of central relevance and the adoption of water conservation policies reduces the scenario based demand increase from 163.3% to 92.9%, still a huge and critical increase.

The relative changes in water demand increase due to the adoption of water conservation policies (first columns of Table 6) show that the largest contraction is that of the Villa segment (excluding the Commercial sector), a relevant result given the segment accounts for more than 50% of the total demand for Qatar. The latter evidence also highlights how the water conservation policies might be tailored to the residential segments, the Villa in particular.

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study analyzes the link between water consumption, population growth and the adoption of water conservation policies in Qatar. The empirical and simulation-based evidence introduced in the paper support the view that an adequate usage of water is a crucial element for controlling the increasing trend of water consumption. The forecasting scenarios provide evidence that water conservation policies, as proxied by a contraction of water elasticity to population, would lead to sensible decreases in water consumption levels compared to a situation where conservation improvements do not take place. The impact of water conservation policies varies across market segments and over different population scenarios. However, the most striking finding is that the water demand in the Villa segment could decrease up to 27% while the drop in the Commercial segment could reach the 46%. These results are particularly relevant as these two market segments represent, over a long-run trend, about 80% of the total water demand of Qatar. These promising evidences call for the adoption of powerful water conservation policies that will have a crucial role in controlling the evolving water demand in Qatar.

ACKNOWLEDGEMENTS

This paper was made possible by NPRP grant # [NPRP10-0131-170-300] from the Qatar National Research Fund (a member of Qatar Foundation) and Qatar University Grant no. QUCP-CBE-2018-1. The statements made herein are solely the responsibility of the authors. In addition, we thank the Conservation and Energy Efficiency Department at KAHRAMAA, the Qatar General Electricity and Water Corporation, for their cooperation and providing us with a detailed dataset that was fundamental for the estimation and forecasting process.

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