Rene Fernando Lara Cervantes[1]

ECONOMIC DEVELOPMENT AND WATER SCARCITY IN MEXICO

This study analyzes water quality in Hydrological-Administrative Region (HAR) XIII of Mexico in order to assess the impacts of stress factors such as economic and population growth. The results emphasize the need for new economic policy design with environmental criteria, whereas wastewater treatment needs to be improved in order to manage water scarcity. Both actions need to involve all the related stakeholders and not only the federal government.

Keywords: *water scarcity; urbanization; population growth; Mexico.*

Рене Фернандо Лара Сервантес

ЕКОНОМІЧНИЙ РОЗВИТОК ТА НЕДОСТАТНІСТЬ ВОДНИХ РЕСУРСІВ: НА ПРИКЛАДІ МЕКСИКИ

У статті проаналізовано якість водного забезпечення гідрологічно-адміністративного регіону 13 в Мексиці з метою виявлення факторів впливу, таких як економічне та демографічне зростання. Результати підкреслили необхідність розробки нової політики в даній сфері з урахуванням екологічних критеріїв. Також необхідно переглянути технології очищення стічних вод. Ці заходи мають бути проведені за участі не тільки центрального уряду, але й усіх відповідних стейкхолдерів.

Ключові слова: *недостатність водних ресурсів; урбанізація; зростання населення; Мексика.*

Табл. 7. Літ. 22.

Рене Фернандо Лара Сервантес

ЭКОНОМИЧЕСКОЕ РАЗВИТИЕ И НЕДОСТАТОК ВОДНЫХ РЕСУРСОВ: НА ПРИМЕРЕ МЕКСИКИ

В статье проанализировано качество водного обеспечения гидрологического-административного региона 13 в Мексике с целью выявления факторов влияния, таких как экономический и демографический рост. Результаты подчеркнули необходимость разработки новой политики в данной сфере с учётом экологических критериев. Также необходимо пересмотреть технологии очистки сточных вод. Данные мероприятия должны быть проведены с участием не только центрального правительства, но и всех соответствующих стейкхолдеров.

Ключевые слова: *недостаточность водных ресурсов; урбанизация; рост населения; Мексика.*

Introduction. Water scarcity is becoming a challenging problem for Mexico to solve, since water availability has been constantly decreasing. Also, the country will face in the near future a stronger pressure over water resources due to spatial distribution, population growth, pollution and water management problems.

In this country water resources have strong territorial and seasonal differentiation; additionally, these is a contradiction with population concentration and GDP generation (Perevochtchikova, 2010). In this regard, Central and North regions of the country which are either arid or semi-arid concentrate most of urban population and produce 87% of GDP (Saltiel, 2008; Seckler et al., 2009). According to Atlas del Agua en Mexico (2014), in 2012 the population reached 117 mln people; however, currently only 20.7% of the total population remain in rural locations, whereas 93.9 mln people are concentrated in urban settlements. With regard to pollution, there is evidence

[1] University of Economics in Prague, Czech Republic.

that the lack of treatment for industrial, agricultural and domestic wastewaters has polluted in different degrees around 96% of water resources (Saltiel, 2008). Also, the quality of underground aquifers is decreasing as a consequence of disorganized urbanization. In the country, groundwater resources provide around 70% of the drinking water supply for the population which is strategic for the driest areas (Carrillo et al., 2008). Location of urban centers in recharge areas of aquifers, deficient sewage and waste disposal infrastructure of the cities and the constantly growing water demand population are worsening the groundwater resources pollution (Jimenez et al., 2010). Reduction of aquifers quality leads to the problem of overexploitation that affects water quality and quantity. Nowadays, Mexico uses 653 aquifers of which 106 are overexploited; also, excessive pumping is leading to major concentration of toxic elements in aquifers such as fluoride and arsenic that could turn into a threat for human health in the near future (Atlas del Agua en Mexico, 2014; Jimenez et al., 2010).

The current water policy is not adequate to cope with the challenges produced by the needs of economic growth and the water demand of urban population. In Mexico since 1983, the provision of water services was decentralized and belongs to municipalities; however, they lack technical experience and financial resources to improve the efficiency of water utilities (Roland et al., 2010). Moreover, the federal government still has a strong intervention in the water sector but the investment needs have surpassed its financial possibilities (Perevochtchikova, 2010).

The research objective is to quantitatively assess through a regression model the demographic, economic and financial factors of urbanization over water availability. In this regard the Hydrological Administrative Region (HAR) XIII Waters of the Valley of Mexico provides a useful case study since it experiences all the problems described above. The paper is organized as follows: literature review on water scarcity and previous studies that address the topic, then goes the problem description and research goals, methodology, data, model specification and estimation, results interpretation, conclusions and policy recommendations.

Literature review.

The causes of waters scarcity. Water scarcity is a worldwide recognized problem that affects especially the less developed countries. Around 1.2 bln people worldwide mostly from developing countries lack access to safe drinking water and by the year 2025 it could reach between 2.7 and 3.5 bln people (Mukheibir, 2010). Overall, these countries are more likely to experience environmental degradation and conflicts. According to B.E. Barbier (1999) developing countries could fall in the poverty – environment trap given that they are highly dependent on natural resources exploitation. Also, natural resources overuse and lack of funds to provide necessary infrastructure are sharpening the impacts of environmental degradation (Cocos et al., 2012). This situation is critical since water is essential for humans, economic development and biodiversity. Therefore, water allocation is an important challenge to address by development planners, with all of its social, political, economic and environmental dimensions (Walter et al., 2011). In this regard, developing countries are more vulnerable to water scarcity given their dilemma between the need for economic growth and rational exploitation of water resources.

Usually water scarcity is defined and measured as a supply problem (physical scarcity); however, it is influenced by political decisions and institutional arrange-

ments. Although climate change is indeed affecting the supply by the modification of hydrological cycles and precipitation regimes, in developing countries institutional arrangements hinder the efficient and sustainable use of water resources (Cocos et al., 2012). According to P. Mukheibir (2010), most of water scarcity indices are measured in terms of physical access to water and ignore power relations, poverty and unequal distribution which are also the causes of water scarcity. In this regard, there is a strong debate about the equitable provision of drinking water and affordable water services and necessary institutional arrangements.

Institutions are considered as constraints that define the structures of political, economic and social interaction. Institutions are composed of informal rules defined by taboos, customs and traditions; and formal rules defined in the political sphere and enforced by authorities (Culas 2006). Moreover, societies with transparent, honest and effective institutions are more successful in abating the environmental degradation than in those countries with high levels of corruption (Duit, 2005). With regard to water provision, in developing countries institutions have the strategic role in securing regular, equitable and sustainable access to water resources. According to A. Wutich (2009), institutions linked to water management should develop flexible rules to cope with water scarcity without compromising social welfare in the future. Thus, as societies become more heterogeneous and water availability decreases, institutions must guide societal behavior through formalized rules of governance (Hearne, 2007). Functionality of institutions is important in explaining variations in water policy and management outcomes. R. Foa (2009) argue that institutions must provide guidelines and incentives for agents and in allocation of resources in order to obtain favorable results. This is critical in developing countries that require adaptive capacities to manage water scarcity. In this regard, institutions should manage water constraints; promote investments for conservation, improvement of efficiency and sustainable use of water resources to avoid the inclusion of new water resources (Mukheibir, 2010). Nevertheless, developing countries have several restrictions to promote institutional change such as the lack of funds and human capital necessary to improve water management. According to T. Walter et al. (2011), these factors hinder the capacity of development planners that lack accurate information and adequate knowledge to assess water policy and develop water policy guidelines.

The referred literature shows that water scarcity is a multidimensional problem that needs to be addressed holistically. Different dimensions require deep understanding of the impacts of water scarcity and its linkages with social welfare, economic development and biodiversity conservation.

Previous studies on water scarcity and water management. The previous studies on water scarcity and management are both qualitative and quantitative. Quantitative studies analyze mostly water demand problems linked to water prices, costs of water supply, development degree and socioeconomic factors. The analysis by A.D. De Maria and J.R. Carvalho (2014) covered price elasticities in the city of Fortaleza given spatial differences income, average, price, number of residents and number of bathrooms in order to assess their sensitivity. F. Destandau and S. Garcia (2014), estimated econometric models to assess the relation of the quality of water services and water production finding that public ownership is more capable of improving both. Also, estimations performed by K. Krause et al. (2003) showed that in order to attain water

conservation goals, they should be compatible with a pricing system based on disaggregated demand.

T. Walter et al. (2011) studied water scarcity in the area of the Middle-Olifants subbasin which is the third most water-stressed basin in South Africa. The authors developed Water Situation Assessment Model (WSAM) for simulations of water allocations among competing uses under scenarios of changes in tariffs, subsidies for the poor and increases in population and urbanization for the year 2050. The authors found that increasing population and urbanization are the key factors of water stress and concluded that efficiency most be addressed to achieve the socio-political objectives in the country and to avoid crisis. However, they concluded that efficiency increases are easy to introduce in a theoretical model but difficult to implement in practice due to legal and institutional barriers. Also, historical differences should be address to provide more water to the needy domestic users, thus, economic criteria alone cannot be the basis for new water management.

A. Cocos et al. (2012) studied the impacts of potential water scarcity in developing countries. The authors analyzed quantitative and qualitative data of the Calnistea area in Romania that has 3 distinct aquifers in order to estimate the surface water and groundwater demand in the region. Their results showed that if problems such as pollution and overexploitation of groundwaters are not reduced, water scarcity could escalate and compromise population welfare. They concluded that in order to address water scarcity, local authorities must develop financial autonomy to manage specific problems such as the lack of water supply systems, sanitation and wastewater treatment in the region.

A. Wutich (2009) studied water management problems in the settlement of Villa Israel in Cochabamba, Bolivia, where most population lives close to the subsistence level and lacks public water supply infrastructure. The author analyzed the data obtained from interviews about water institutional governance performed to key informants and households between 2003 and 2005, with the follow-up in 2008. The author found that local institutions are strategic for users to organize independently to address contextual problems and control water allocations in the event of water scarcity.

The previous studies stressed the relevance of demographic, socioeconomic, environmental and institutional arrangements which will be basis for out following analysis.

Description of the problem and the research objective.

Situation of the Hydrological-Administrative Region XIII Waters of the Valley of Mexico. Mexico is divided into 13 Hydrological-Administrative Regions (HARs) and most of them suffer from certain degree of water stress. According to "Estadisticas del Agua en Mexico" (2014), the HAR XIII Waters of the Valley of Mexico is the most representative case since it shows very high stress over water resources. In this region, water withdrawals from surface water and groundwater sources were 137.8% more than its yearly renewable water catchment thus compromising the drinking water supply. This area is as well the smallest HAR of the country; however, of 13 HARs it is at the same time the most populated. The HAR XIII has population density 24 times larger than the national average (Estadisticas del Agua de la Region Hidrologico-Administrativa XIII, Aguas del Valle de Mexico, 2009). Moreover, the quality of its

water resources is decreasing. As demonstrated by the statistics of the National Water Commission (Conagua), in the period of 2003–2012, approximately 64% of water resources of the region were considered to be polluted or extremely polluted. Although in the same period of time it contributed almost 25% of the national GDP. It must be stressed that this situation is the result of an inappropriate design of water policy and institutional arrangements enforcing sustainable water management.

Although information about regional water management by HAR is scarce, water management problems are very similar among the areas with water scarcity. After decades of centralized water management, in 1983 the process of decentralization was initiated aiming to increase the efficiency of the water sector (Vasquez et al., 2011). The process aimed to increase the participation of municipal and states governments since they were assumed to have better knowledge of regional water problems and more incentives to use efficiently water resources. However, this was not necessarily true since in Mexico after the decentralization, water utilities have not substantially improved their efficiency. As stressed by L. Roland et al. (2010), municipalities lacked technical experience and resources for proper water management; thus, the federal government created Conagua to assist the municipalities.

The transfer of responsibilities failed since Conagua owns the largest share of investments in water utilities. This is shown in Table 1.

Table 1. **Investment in the water sector in 2013,** *elaborated from* (Estadisticas del agua en Mexico, 2014: 129)

	Federal government investment (CONAGUA)	States investment	Municipalities investment	Private sector investment	**Total investment**
Investment, *mln pesos*	22,984.4	5,880.5	3,296.1	4,952.0	**37,113.1**
Share in the total investment, *%*	61.9	15.8	8.9	13.4	**100**

It is possible to assume that water management is still centralized; however, the needs of the water sector have surpassed the financial possibilities of the federal government. The increasing stress on water resources is disappearing springs, the bases of rivers and ecosystems as such; also, the costs of extraction are higher and water quality is decreasing which could lead in the near future to a considerable reduction in water per capita availability (Arreguin, 2010).

Given the features of HAR XIII Waters of the Valley of Mexico, this research will assess the impacts of demographic, economic and financial factors over the quality of water resources of the region which is critical to manage water scarcity. The goal is to weigh the contribution relevant factors affecting water quality in order to determine which should be the priorities of water policy.

Methodology, data and model specification. Estimation of the relative weighs of the variables will be performed using OLS regression model. The data to perform the analysis was obtained from the National System of Water Information (SINA) and consists of a time series for the period 2003–2012, the information includes data on pollution of water resources, population size, GDP share, wastewater treatment and economic resources for investment in HAR XIII Waters of the Valley of Mexico.

Description of the variables, model specification and the expected impact of the independent variables are given in Table 2.

Table 2. **Description of the variables and model specification**

Variable type	Name of variable	Variable description	Expected result
Dependent variable	Polluted water resouces (PWR)	% of polluted and heavy polluted water resources based on the Biochemical Oxygen Demand (BOD)	
Independent variables	Collection of water rights (CWR)	mln pesos collected by the federal government from water concessions.	$\beta_1 < 0$
	Public water supply (PWS)	volume of hm^3 used for public water supply	$\beta_2 > 0$
	Gross Domestic Product (GDP)	share as % of GDP	$\beta_3 > 0$
	Wastewater management	volume in m^3/s of treated wastewater	$\beta_4 < 0$
	Population (POP)	mln of inhabitants	$\beta_5 > 0$

Estimation and interpretation of results. The results of the estimation for HAR XIII Waters of the Valley of Mexico are shown in Table 3.

Table 3. **Regression results for HAR XIII Waters of the Valley of Mexico**

Variable	Coefficient	Significance
Constant term	214.797	Statically not significant
Collection of water rights (CWR)	.724	Significant at 10%
Public water supply (PWS)	-.466	Statically not significant
Gross Domestic Product (GDP)	.555	Significant at 10%
Wastewater management (WM)	-.129	Statically not significant
Population (POP)	-1.023	Significant at 10%
R^2/Adjusted R^2	.868/.703	

The selected variables seem to explain relatively well the variation of water quality. However, the size of the sample affecting model stability and results accuracy is limited due to heteroskedasticity problems. The variables statistically not significant were kept since they are acknowledged in literature as the factors that affect water quality; however, there are some contradictory results.

WM and GDP had the expected results as consistent with the literature associated with the dilemma of rational use of natural resources and the need for economic growth in developing countries. Given the coefficients, water quality in Mexico is very vulnerable to increases in economic activity; however, water quality could also be improved if wastewater treatment capacity is increased.

The main contradictions are POP and PWS since they show that increase in population and in municipal water supply would improve water quality; whereas in literature they are acknowledged as the factors of water stress. The impacts of CWR are also contradictory but could be explained to some extent. An increase in the collection of water rights does not necessarily means more federal investment in the water sector, thus, increased water concessions lead to higher profits but also to increase water pollution if additional funds are not invested in infrastructure improvement.

Conclusions and policy recommendations. The analysis confirms the need to develop more precise and comprehensive data in order to address regional differences in water management in Mexico. The lack of regional data was most likely caused by partial decentralization which has not yet improved local institutional capacities necessary to cope with water scarcity.

Moreover, water scarcity has been the product of the combination of physical stress and policy priorities linked to economic growth. This was shown in the analysis of the HAR XIII Waters of the Valley of Mexico which showed the negative impact of economic growth in water quality. Thus, economic policy must be designed with environmental criteria so that water scarcity would not increase. The results stressed as well that infrastructure improvement for wastewater treatment should be the top priority. Once again, this could be more easily addressed through the development of financially autonomous local and regional institutions that could find more adequate solutions for strategic regional problems

If these facts are ignored, water scarcity could escalate until political and social conflicts outbreak in the country.

Acknowledgements. *This paper is a result of project IGA No. F2/26/2014 "Impact of economic liberalization on environment al policy".*

References:

Atlas del Agua en Mexico 2014 // www.conagua.gob.mx.

Barbier, B.E. (1999). Endogenous Growth and Natural Resource Scarcity. Environmental and Resource Economics,14: 51–68.

Carrillo, R., Cardona, J.J., Huizar, A.R., Ganiel, E. (2008). Response of the interaction between groundwater and other components of the environment in Mexico. Environmental Geology, 55: 303–319.

Cocos, A., Cocos, O., Sarbu, I. (2012). Coping with water scarcity: the case of the Calnistea catchment (Romania). Environment Earth Science, 67: 641–652.

Culas, J.R. (2006). Deforestation and the Environmental Kuznets Curve: An Institutional Perspective. Ecological Economics, 61: 429–327.

De Maria, A.D., Carvalho, J.R. (2014). Spatial Determinants of Urban Residential Water Demand in Fortaleza, Brazil. Water Resource Management, 2401–2412.

Destandau, F., Garcia, S. (2014). Service quality, scale economies and ownership: an econometric analysis of water supply costs. Journal of Regulatory Economics, 46: 152–182.

Duit, A. (2005). Understanding Environmental Performance of States: an Institution-Centered Approach and some Difficulties. QOG Working Paper Series, 1–17

Estadisticas del Agua de la Region Hidrologico-Administrativa XIII, Aguas del Valle de Mexico 2009 // www.conagua.gob.mx.

Estadisticas del Agua en Mexico 2014 // www.agua.org.mx.

Foa, R. (2009). Social and Governance Dimensions of Climate Change: Implications for Policy. Social Development Working Papers, 1–35.

Hearne, R.H. (2007). Evolving Water Management Institutions in the Red River Basin. Environmental Management, 40: 842–852.

Jimenez, C.B., Duran, A.J.C., Mendez, C.M.J. (2010). Calidad. In: El Agua en Mexico: cauces y encauces (pp. 265–290) // www.conagua.gob.mx.

Krause, K., Chermak, J.M., Brookshire, D.S. (2003). The Demand for Water: Consumer Response to Scarcity. Journal of Regulatory Economics, 23(2): 167–191.

Mukheibir, P. (2010). Water Access, Water Scarcity, and Climate Change. Environmental Management, 45: 1027–1039.

Perevochtchikova, M. (2010). Los grandes problemas de Mexico: medio ambiente, Chapter 2 // aleph.academica.mx.

Roland, L., Cardenas, Y.V. (2010). La gestion del agua en Mexico. Polis, 6: 155–158.

Saltiel, G. (2008). Problematica del sector de agua, alcantarillado y saneamiento mexicano-analisis. In: El agua potable en Mexico: Historia reciente, actores, procesos y propuestas, ejemplos y propuestas (pp. 229–236) // www.aneas.com.mx.

Seckler, D., Barker, R., Amarashinge, U. (1999). Water Scarcity in the Twenty-first Century. International Journal of Water Resources Development, 15: 29–41.

Vasques,W.F., Franchesci, D., Van Hecken, G.T.J.A.J. (2011). Household preferences for municipal water services in Nicaragua. Environment and Development Economics, 17: 105–126.

Walter, T., Kloos, J., Tsegai, D. (2011). Options for improving water use efficiency under worsening scarcity: Evidence from the Middle Olifants Sub-Basin in South Africa. Water SA, 37: 357–367.

Wutich, A. (2009). Water Scarcity and the Sustainability of a Common Pool Resource Institution in the Urban Andes. Human Ecology, 37: 179–192.

Statistical appendix

Table A1. **Model summary**

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.932[a]	.868	.703	7.650

[a] Dependent Variable: % of aquifers contaminated and heavily contaminated.

Table A2. **Analysis of variance (ANOVA)**

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	1537.924	5	307.585	5.256	.067[b]
	Residual	234.076	4	58.519		
	Total	1772.000	9			

Table A3. **Regression coefficients**

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	214.797	234.749		.915	.412
	Collection of water rights (CWR), mln pesos	.024	.009	.724	2.598	.060
	Population (POP), mln inhabitants	-1.989E-005	.000	-1.023	-2.217	.091
	Gross Domestic Product (GDP), %	12.306	5.840	.555	2.107	.103
	Wastewater management, m³/s	-4.043	11.188	-.129	-.361	.736
	Public water supply (PWS), hm^3	-.021	.011	-.466	-1.971	.120

Table A4. **White Heteroskedasticity Test**

F-statistics	4.14992455954647	Probability	0.36331090372567
Obs*R-squared	9.70759717918096	Probability	0.286151441519627

Стаття надійшла до редакції 23.01.2016.