Title: Water pricing under climate uncertainty – an economy-wide model considering precipitation stochastics

Abstract:

Until today uncertainty of input parameters has not often been systematically analyzed in computable general equilibrium (CGE) modelling (Seung and Lew, 2013). Especially this is true when it comes to climate uncertainty (Thurlow et al., 2012), although it is generally projected that climate variability will increase in the future and thus its welfare implications will become more crucial (Thornton et al., 2014). Instead, CGE models are mostly applied in a deterministic setup making their findings highly dependent on point estimates of key exogenous variables. Sensitivity analysis is often conducted by simply adding scenarios, setting the levels of key input variables to more extreme values. However, this ignores the statistical distribution and thus the probability of the selected scenarios.

A way to deal with uncertainty in a more systematic manner is the integration of stochastics. Thurlow et al. (2012), Sassi and Cardaci (2013) and Solymani (2017) are among the few publications of this kind, integrating Monte Carlo approaches into CGE models to account for uncertainty of climate conditions. In the three publications the impact of rainfall variability on cereal production and ultimately food security is analyzed for Bangladesh, Sudan and Malaysia, respectively. Above that Thurlow et al. (2012) also include effects of flooding and sea-level rise. The integration of a stochastic model for climate variability allows the authors to attach a probability interval to the range of output-variables received.

All the previous studies focus on the effects of climate variability on agriculture and largely do not account for direct effects on other sectors. Also the chosen sample sizes for the Monte Carlo model (which varies between 50 and 5000 iterations in the studies cited above) is not further justified.

In this study, we employ the Monte Carlo approach to simulate uncertainty of annual rainfall induced freshwater recharge in Israel. As in Israel the water withdrawal rate is close to 100% of available freshwater sources (and sometimes above), this directly affects water supply. We integrate the stochastic variability of rainfall induced freshwater recharge in a computable general equilibrium (CGE) model, which includes a detailed depiction of water supply and demand. Doing so we can, different from previous approaches, analyze the direct effects of climate uncertainty on all economic sectors as well as on households' water supply. Furthermore, alternative water sources, such as desalination and reclamation of wastewater are included in the model. Their capacities have been expanded in Israel in recent years in order to become more independent from rainfall variability. Yet, it is discussed whether additional capacity is required, or whether expensive overcapacities are created (Reznik et al., 2016). Moreover, what would be an efficient potable water price given the uncertainty of freshwater resource availability is under debate.

Based on this background, we apply our approach to determine the minimum water price that should be charged in order to avoid overexploitation of natural freshwater resources with 90% confidence under different desalination-capacity regimes and compare the economy wide and household-level welfare effects between the different scenarios.

In order to generate the stochastic components for the uncertainty analysis, the data of annual recharge of freshwater aquifers from rainfall of the period from 1973-2009 is used (Weinberger et al., 2012). According to the Dickey-Fuller and the Augmented Dickey-Fuller tests the data series are found to be stationary at the 5% significance level. Therefore, for separating the stochastic components of the data the deviates of the values from the mean calculated in shares are used (Burrell and Nii-Naate, 2013). The calculated deviates are found to be normally distributed at the 5%

level according to the following normality tests: Chi-squared; Kolmogorov-Smirnov; Shapiro-Wilks; Anderson, Darling; Cramer-von Mises. Since a negative water availability shock cannot be higher than -100%, the normal distribution is truncated at a minimum value of -1. The Latin Hypercube Sampling (LHS) method is applied to randomly draw values from this distribution. This method divides the distribution into equal intervals and from each interval randomly draws one value, thus making sure that the randomly selected points are evenly distributed across the sampling space. These points are then fed into the CGE model as deviations from the average annual natural fresh water supply. In order to determine a sufficient sample size systematically, the CGE-model is run, stepwise increasing the number of iterations based on an increasing sample size and the resulting coefficients of variation of the potable water price are compared. This procedure is continued until a further increasing sample size does not lead to a change in the coefficient of variation larger than 1 percentage point.

Preliminary findings suggest that the current pricing scheme guarantees only in about 45% of the years that water demand remains below the annual renewable freshwater recharge rate. In order to avoid over drafting of in 90% of the years, demand for water from natural freshwater aquifers would need to be reduced by about 43%. This could be achieved by doubling potable water prices for all users. The overall effect of on the economy of such a price increase would be relatively small, resulting in a drop of GDP by 0.02%, as water constitutes only a small expenditure share in the production of most commodities and services. Additionally, there are other sources of water available (desalination, reclamation of freshwater, brackish groundwater), as well as water saving technologies which help to diminish the impact of a curtailed supply of water from natural freshwater sources. On the household level the welfare effects are relatively strong and overall negative, but differ according to income-quintile, resulting in a redistribution of welfare: The equivalent variation as share of base household expenditure varies between:+5.5% and -3.6% for the poorest and richest households, respectively, mostly driven by income effects.

In order to reduce dependency on natural fresh water sources further and guarantee a more reliable potable water supply, the desalination-capacity could be further expanded. A simulation shows that if the desalination capacity was doubled, potable water prices would only need to be increased by about 21% in order to avoid over drafting of freshwater resources. The effect on GDP would not be much different, but effects on household-welfare would be much more balanced and less negative.

Sources:

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