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## Controlling omitted variables and measurement errors by means of constrained autoregression and structural equation modeling

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# Chapter 6      **Conclusions, Policy Recommendations and Suggestions for Further Research**

## **1. Summary and conclusions**

The main overall purpose of this thesis is to shed further light on the preferences for in-house piped water in rural and urban Indonesia. To achieve this goal, the thesis addressed the following objectives. First, since in the data set available to analyze the overall objective –like in many other (panel) data sets in the social sciences- several systematic explanatory variables were missing, I introduced constrained autoregression (CAR) and structural equation modeling (SEM) – ASEM - as combined methodology to control time-varying omitted variables and measurement error. Second, I compared the performance of CAR to the commonly used alternative methods to control time-varying omitted variables, viz. the latent fixed effect model, first order differencing regression, demeaning regression, and the autoregressive model. Third, I developed a likelihood ratio (LR) test of CAR in the presence/absence of omitted variables. Finally, I applied ASEM to analyze the preference for in-house piped water in rural and urban Indonesia.

### **Objective 1: Constrained autoregression – structural equation modeling (ASEM) to control time-varying omitted variables and measurement error**

For the first objective I found that ASEM performs well to control time-varying omitted and thus supplements standard econometric procedures like first-order differencing. Another important characteristic is that ASEM requires no external information to handle measurement error. The performance of SEM to control measurement error is well documented in the literature (see inter alia Jöreskog and Sörbom (1996) and Bollen (1989). The application to urban Indonesia presented in Chapter 2 showed that omitted

variables and measurement errors in explanatory variables should be handled simultaneously, as done by ASEM.

**Objective 2: The performance of CAR compared to the commonly used alternative methods to control time-varying omitted variables, viz. the latent fixed effect model, first order differencing regression, demeaning regression, and the autoregressive model.**

This objective was analyzed by means of Monte Carlo simulation. The main findings are the following. First, the time-variant approaches to control omitted variables outperform the time-invariant methods in terms of bias and mean squared error. A second finding is that autoregression is inferior to constrained autoregression for virtually all simulation parameters values. Thirdly, analysis of the impacts of the simulation parameters on the bias showed that for the time-invariant correction procedures and for the autoregression approach the bias left in the estimator of a regression coefficient after controlling for the omitted variable is a complicated function of notably the covariances among the included variables and the omitted variable, and of the autoregression coefficients of the omitted variable and of the regressors. Only in the case of CAR, the impacts of the determinants on estimator bias are very small.

**Objective 3: A likelihood ratio (LR) test of CAR in the presence/absence of omitted variables.**

This objective was also analyzed by means of Monte Carlo simulation. The main finding was that the probability of a Type I error of no omitted variable (NOV) CAR model specification is less than the pre-specified level of 0.01 virtually everywhere while the power of the test of CAR based on the correct hypothesis of omitted variables is 1 everywhere. Another finding is that the test is highly sensitive to the autoregression of the

omitted variable. The main outcome of Chapter 4 is that the likelihood ratio test of NOV versus CAR can be effectively applied to decide whether or not to apply CAR.

**Objective 4: Analysis of the preference for in-house piped water in rural and urban Indonesia.**

The analysis of this objective was based on the Indonesia Family Life Survey (IFLS). The main finding was that households in urban and rural areas have approximately the same willingness to pay (WTP) for in-house piped water, relative to monthly household expenditure. Particularly, in-house piped water increases the average of house rent appraisal by 34.24% which is equivalent to 5.18% and 3.22% of *monthly household expenditure* (on food and non-food items) in urban and rural areas, respectively. The difference between urban and rural areas was tested by means of multi-sample analysis. The test failed to reject the null hypothesis of no difference between urban and rural areas. For the 25% households with the lowest expenditure levels, the rent appraisal estimates for urban and rural areas are equivalent to 9.41% and 7.57%, respectively. These results are higher than the outcomes from earlier studies on actual expenditure on vended water by poor households in Indonesia. Possible explanations for the increase are: (i) piped water has better quality, accessibility and availability than vended water; (ii) during the past 20 years, awareness of the importance of piped water has increased and the availability and quality of natural water sources has deteriorated while (iii) people are better informed about the risks of consuming polluted water.

## **2. Recommendations**

### ***Methodological recommendations***

In this thesis I have shown that ASEM is an effective vehicle to control omitted variables and measurement error. Particularly, the CAR component of ASEM is superior

to a variety of alternative procedures commonly applied to reduce omitted variable bias. Another advantage is that it does not require additional information. The decision to adopt CAR versus a model without omitted variables controls can be effectively tested by means of a likelihood ratio test. A further advantage of CAR is that it can be combined with SEM to simultaneously control omitted variables as well as measurement errors. Its use in empirical studies is strongly encouraged.

### ***Policy recommendations***

Currently, 82% of the Indonesian population is served by improved water supply. However, the prevalence of water borne diseases is still high in Indonesia. In total, poor sanitation and hygiene contribute to 120 million disease incidents and 50 thousand premature deaths annually (Pinto, 2013). The high prevalence of waterborne diseases relates to the quality of water extracted from lakes and rivers, but also from wells and springs. Particularly, current rapid environmental degradation has deteriorated the quality, as well as decreased the availability, of natural clean water. Water from wells and springs has deteriorated due to infiltration of contaminated surface water. Under these conditions of deteriorated water quality, extension of piped water into dwellings or yards (denoted in-house piped water in the sequel) is the most effective mode to improve health in developing countries like Indonesia (Hutton and Haller, 2004).

Among the 82% of Indonesian population served by improved water supply, only 20% of is served by in-house piped water service. The distribution between rural and urban Indonesia, however, is skewed. Of the rural population only 8% is served while the service covers 36% of the urban population (WHO-UNICEF, 2013). The gap between urban and rural is related to the prevalent policy of domestic water supply. Particularly, the GoI has concentrated in-house piped water investments mainly in urban areas. In rural areas, it has promoted alternatives, such as public wells, taps or hydrants. For

instance, the rural water and sanitation project, 'PAMSIMAS', focuses on public taps and hydrants in 5000 villages only, which is a small fraction of the 79075 villages in rural Indonesia. Furthermore, of the 4,217 piped-water connections in 2012, only 218 were in-house connections. Most of the project was dedicated to the provision of public taps (3467 units) and public hydrants (532 units) (PAMSIMAS, 2013).

The WTP estimates obtained in this thesis imply that urban and rural households have approximately the same strong relative preferences for in-house piped water. The findings are relevant for water provision in Indonesia. Particularly, the GoI should reconsider its policy to give priority to urban areas. The findings in this thesis show that in both rural and urban areas, there is a strong preference for in-house piped water and that both areas should be targeted.

The estimates also show that the average WTP of poor households is well above the World Bank's "affordability" benchmark of 5% of total income. Moreover, the relative WTP of poor households is higher than that of wealthier households. Accordingly, they should be prioritized. However, if the government decided to apply a full recovery scheme, high water tariffs would result which would deter poor households from connecting to the system (Jalan et al., 2009). Instead, they would divert to less safe but affordable modes. Therefore, the government should reconsider support systems, such as subsidies, where they are in place, and introduce them where they are not (see also van den Berg and Nauges 2012). Alternatively, the government might consider a block tariff system with the first block free of charge for the poor (Majumdar et al. 2009).

### **3. Suggestions for further research**

The constrained autoregression model was recently introduced (Suparman et al., 2014a). Consequently, applications of it are still very limited (Suparman et al., in press only). Hence, more empirical studies are needed to establish its usefulness. In addition, further theoretical developments are required to adapt it to applications in various specialized areas of regression analysis, e.g. spatial and state space regression. For instance, Oud and Folmer (2008) and Folmer and Oud (2008) show that SEM can be extended to control spatial spillover effects and to model spatial dependence as a latent variable, respectively. Integration of CAR and ASEM into these kinds of spatial models would be an interesting topic for further methodological research.

Regarding piped water, its accessibility in urban and rural areas will generate substantial welfare improvements by reducing morbidity and mortality due to water-borne diseases, particularly for the poor households. In addition, piped water connections may increase households' real income (Nauges et al. 2009) and hence contribute to the reduction of the disparity between the rich and the poor. However, extension of the piped water system will be costly. Therefore, further studies on financing of the extensions are required.

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