Policy Research Working Paper 6029

# Adapting Road Procurement to Climate Conditions

*Atsushi Iimi*
*Radia Benamghar*

The World Bank
Office of the Chief Economist
Sustainable Development Network
&
Transport Unit
South Asia Region
April 2012

Policy Research Working Paper 6029


## Abstract

The world's climate is changing. It is well recognized that technical standards and project specifications of public infrastructure have to be adjusted, depending on the climate. However, it is less recognized that the public infrastructure procurement also needs to be adjusted. This paper examines a particular case of rural road procurement in Nepal. Severe weather conditions, such as heavy rains and storms, are likely to interrupt civil works and wash away unpaved or gravel roads. It is found that heavy precipitation causes delays, but not cost overruns. The paper also shows that budgetary efficiency and credibility could be improved by taking climate conditions into account. If future precipitation were anticipated by backward-looking expectations, many large project delays could be avoided. If the autoregressive precipitation model were used, the vast majority of the observed delays could be eliminated.


This paper is a product of the Office of the Chief Economist, Sustainable Development Network; and Transport Unit, South Asia Region It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at aiimi@worldbank.org.

**Adapting Road Procurement To Climate Conditions** [‡]


Atsushi Iimi[♣ † ¶]

Radia Benamghar[§]



Key words: Public procurement; rural roads, ex post contract adjustments, climate conditions.

JEL classification: D44, H54, H57, D82.


---


[♣] Corresponding author.

[†] Office of the Chief Economist, Sustainable Development Network. The World Bank.



[¶] I express my special thanks to Department of Local Infrastructure and Agricultural Roads (DOLIDAR), District Development Committees (DDCs), Department of Hydrology and Meteorology, Ministry of Environment, and the Nepal Office of United Nations for their kind collaboration in collecting relevant data for this study. I am also grateful to many seminar participants from the DORIDAR, RAIDP, Department of Road (DOR), DDCs, District Technical Offices (DTOs), Office of Auditor General (OAG) and DFID for their insightful comments.



[§] South Asia Sustainable Development Transport. The World Bank.

## I. INTRODUCTION

The world's changing climate is adding various challenges to public road procurement. Particularly, the rural road sector in developing countries has difficulties, because rural roads are often unpaved or simply gravel. These low-standard roads are vulnerable to severe weather conditions, such as flood and heavy rain. In addition, heavy rains and storms also affect the implementation of road works, causing project delays and cost overruns.

In general, ex post contract adjustments incur significant costs to the economy. Efficiency in auctions would be undermined, since the winning bidder may turn out not to be the lowest-cost contractor. Renegotiation is also costly for procurers or governments, because they often have little bargaining power at the post-award stage. They may have difficulty declining opportunistic contract amendments. Further, the budgetary credibility and efficiency would also be ruined if cost overruns or delays happen. In Africa, for instance, one-third of the budget allocated to infrastructure is not executed on time (Briceno-Garmendia, Smits and Foster 2008).

Public resources available for rural road development are far below the needs in developing countries. About 900 million rural dwellers worldwide are estimated to still live outside more than 2 kilometers—a 20 to 25 minute walk—of an all-weather road (Roberts, Shyam and Rastogi, 2006). Without sustainable access to good roads, people will have to spend a lot of time to go to a school, hospital or market. In Nepal, it takes more than 1 hour for rural residents to go to the nearest health post (Nepal CBS, 2004). The lack of rural road access also complicates social and gender issues. Many women and children are still spending several hours a day to collect water and firewood (e.g., WHO and UNICEF, 2006).

Public procurement is an important policy tool to use limited public resources efficiently. However, the road sector has been faced with particular challenges, such as limited competition, weak implementation capacity of local contractors, low governance in the public administration, and imperfect sustainability in road maintenance (e.g., Olken, 2007;

Estache and Iimi, 2011; Benamghar and Iimi, 2011). On top of that, the changing climate is adding an additional complication.

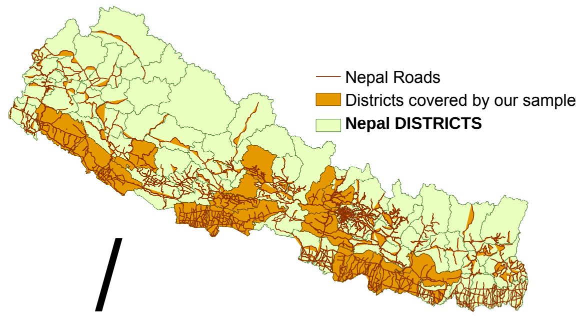
This paper focuses on examining the impacts of expected and unexpected rain on the performance of public rural road contracts in Nepal. Ex post contract adjustments, such as project delays and cost overruns, have long been problems in public infrastructure projects (e.g., Flyvbjerg *et al*., 2002; Guasch, 2004; Alexeeva *et al.*, 2008). By identifying the major determinants of project delays and cost overruns, the paper aims at exploring ways to accommodate climate conditions in public procurement and restrain ex post contract adjustments. The remaining sections are organized as follows: Section II describes the data. Section III develops our empirical method. Section IV discusses the main estimation results and policy implications. Then Section V concludes.

## II. DATA

The empirical data are collected from rural road procurement in19 districts of Nepal where the World Bank has been assisting the Rural Access Improvement and Decentralization Project (RAIDP).[1] They are located mostly in the Tarai area (Figure 1). In each district, on average 8 road contracts were reviewed—half from World Bank-financed projects and half from government-owned projects. In Nepal the rural road projects are implemented at the local level. With the assistance of the Department of Local Infrastructure and Agricultural Roads (DOLIDAR), the District Development Committees (DDCs) are designing, procuring and managing rural road civil works and services.

[1] One of the 20 districts assisted by the RAIDP does not have any evaluable road works yet.

**Figure 1. Existing road network and districts covered by our sample**




Source: Benamghar and Iimi (2011).

The public contracts in the sample are relatively low-value, but the contract performance has not been satisfactory. Many delays and cost overruns have been experienced. In the sample, the projects were delayed on average about 100 days. This is significant compared to an average contract duration of 185 days. About 10 percent of the projects delayed more than one year. Cost overruns are also prevailing. Cost underruns occurred in some cases, but half the contracts underwent cost overruns. The average cost overrun rate is about 4 percent with some cost overruns offset by cost underruns.

Ex post adjustments depend on internal and external factors.[2] Weather is among the most important factors in Nepal. For instance, it rains a lot particularly during summer. In the sample, the district average precipitation is about 200 mm per month (Figure 2).[3] Heavy rains are likely to interrupt civil works and cause project delays, because contractors may not be able to convey the necessary road work equipment, such as pavers, and other materials on time.

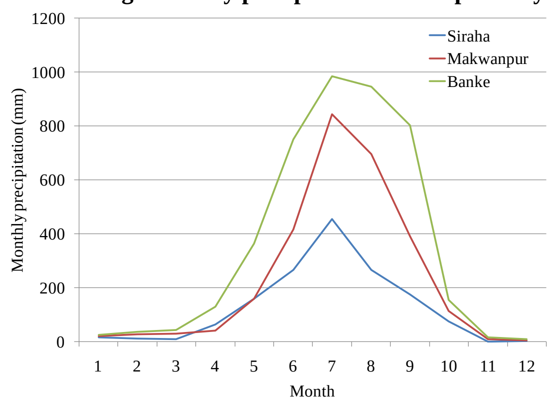
Road procurement often has a cyclical pattern every year. In the case of Nepal, road works are started throughout the year but tend to be launched from April to July (Figure 3). This

[2] See Benamghar and Iimi (2011) for further detailed discussion.
[3] The precipitation data are based on only 20 weather stations that are close to our surveyed roads. There may be a certain measurement error, since the data are district-specific. In each district, there may be a variation in precipitation, depending on location. From the empirical point of view, however, it is worth noting that our precipitation variable is time-variant, not fixed to districts.

may reflect Nepal's fiscal year cycle, which runs from July 16 through July 15. There may be some administrate pressure to execute the budget toward the end of each fiscal year.[4] On the other hand, there is also another peak to start public works in the first quarter of the fiscal year.

In Nepal many road contracts are made before the end of the fiscal year (July) and the actual works tend to be started after the rainy season. Rural road works can last several months to more than one year (Figure 4). For technical reasons, the works can be affected by the climate, depending on work specification. Concrete or bitumen work cannot be implemented during the rainy season. The data indicate that cost overruns and project delays seem to depend on when the work is started. Suppose that the sample is divided into two seasons: rainy (May-September) and dry (October-April). More cost overruns and delays occurred in the rainy season. The distribution of project delays in the rainy season has a relatively thicker tail on the right hand side (Figure 5).

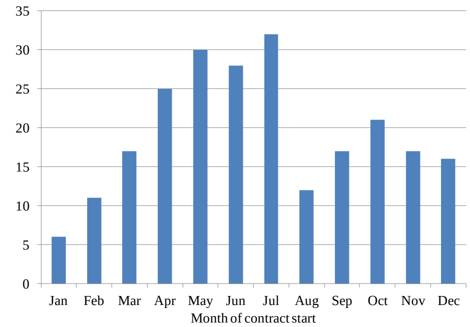
**Figure 2. Average monthly precipitation for the past 10 years**




Source: Author's calculation based on data from the Ministry of Environment, Nepal.

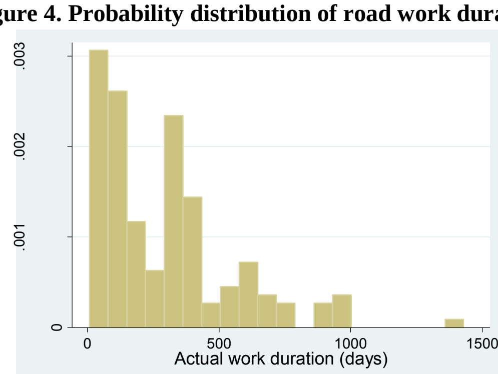
[4] For some of the sample projects, there is a view that the work schedules in contracts are determined by the remaining number of days in the current fiscal year, regardless of the work period estimate from the engineering point of view. This may attribute to the observed massive project delay on average.

**Figure 3. Number of rural road contracts by month of work start**




Source: Author's calculation.

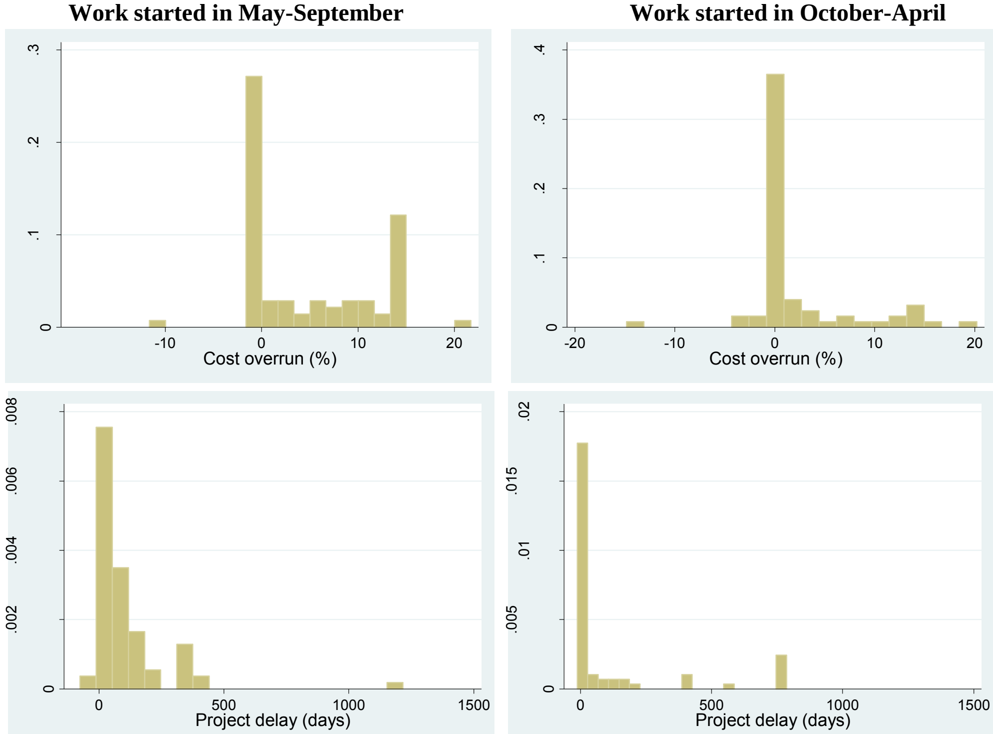
**Figure 4. Probability distribution of road work duration**




Source: Author's calculation.

**Figure 5. Density distributions of cost overruns and delays**

**Work started in May-September** **Work started in October-April**



## III. EMPIRICAL MODEL

Consider the following ex post contract adjustment models of project costs and work schedule:

$$overrun = \alpha_0 + \alpha_1 \ln rain^t + X'\alpha_2 + \varepsilon_1 \quad (1)$$

$$\ln delay = \beta_0 + \beta_1 \ln rain^t + X'\beta_2 + \varepsilon_2 \quad (2)$$

where *overrun* is the rate of cost overruns relative to the original contract amount. *delay* is the number of days for which a project is delayed compared to the planned contract duration.

$rain^t$ measures the amount of total precipitation that actually fell over the actual project implementation period. This can be disaggregated to three different factors (Figure 6). First, future precipitation may be able to be anticipated to a certain extent, although uncertainty always remains. Given the original work schedule, one can predict the future precipitation before the project (denoted by $rain^e$). But this may or may not be accurate. With unanticipated precipitation added (or extracted), a certain amount of precipitation actually falls during the original work schedule (denoted by $rain^a$). Finally, there is another unexpected precipitation associated with ex post changes in work schedule. If a project is delayed, the chances that the project would be affected by precipitation would become higher. Conversely, if a project is completed before the scheduled date, the risk of ex post adjustments can be reduced.

Therefore, the following decomposition is considered:

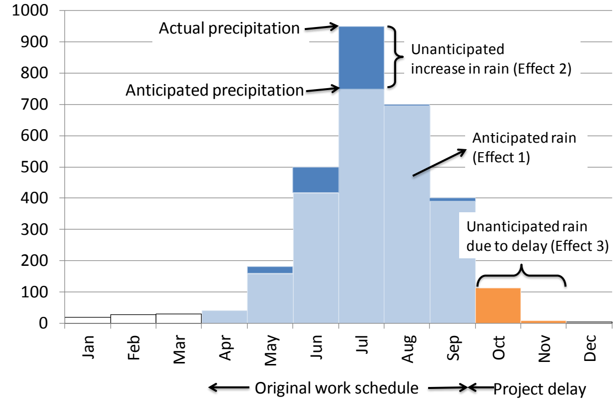
$$\ln rain^t = \gamma_1 \ln rain^e + \gamma_2 \ln \frac{rain^a}{rain^e} + \gamma_3 \ln \frac{rain^t}{rain^a} \quad (3)$$

Note that this specification allows us to not only identify the above-mentioned three effects of precipitation but also avoid logarithms of negative values. Recall that the actual precipitation can be greater or smaller than the anticipated. In Equation (3), the second component is the ratio of actual to expected precipitation during the original work schedule. This will capture the impact of unanticipated weather events on cost overruns or project delays. Figure 7 shows the relationship between the anticipated and actual precipitation in our sample.[5] The observations are not necessarily on the 45-degree line, meaning that expectations may or may not be correct. But they are scattered along the line. Thus, even a simple expectation method has power to predict future precipitation.

The last component in Equation (3) is the ratio of the total precipitation including the extended project period to the precipitation during the original work schedule. Accordingly, this is expected to capture the impact of precipitation associated with project delays. If a project delays, the ratio may increase exceeding unity. Figure 7 depicts this relationship. Above the 45-degree line, the projects experienced certain delays. When a project is completed before the schedule, it is plotted below the 45-degree line. Interestingly, the implications of advance and delayed completion look asymmetric. When a project is delayed, much more precipitation would fall during the extended period. It means that more delays would happen during the rainy season. By contrast, if a project is completed before the schedule, the amount of precipitation is, by definition, less than expected, but the difference does not look so significant. This may be because the early completion would likely happen during the dry season.

[5] See the following discussion on how to construct precipitation expectations.

**Figure 6. Decomposition of anticipated and unanticipated precipitation during the project implementation period**




Source: Author's illustration.

**Figure 7. Actual precipitation and backward-looking expectations during the original work schedule**

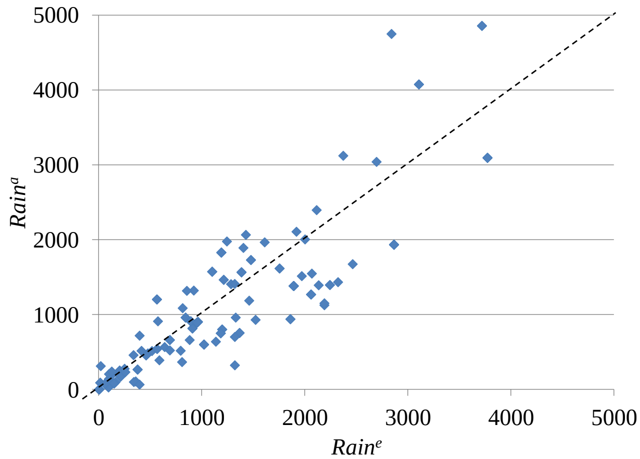
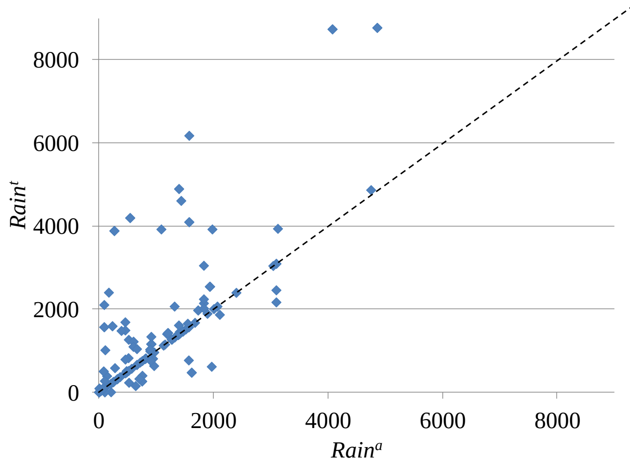



**Figure 8. Precipitation during the original work schedule and precipitation during the actual work period**



Various techniques exist to predict future precipitation, $rain^e$. One practical and computationally easy way is to assume that this year's precipitation would be the same as the last year's. Given the original work schedule, expected precipitation can be calculated by adding up monthly precipitations during the same period last year.[6] This is a simple backward-looking expectation but considered as a good prediction in our case, because the Nepal's precipitation data exhibit similar seasonality every year (Figure 9). In addition, the project duration of our sample projects is relatively short, up to one year and half. Therefore, at least in the short run, the simple backward-looking expectation is a good forecast method.

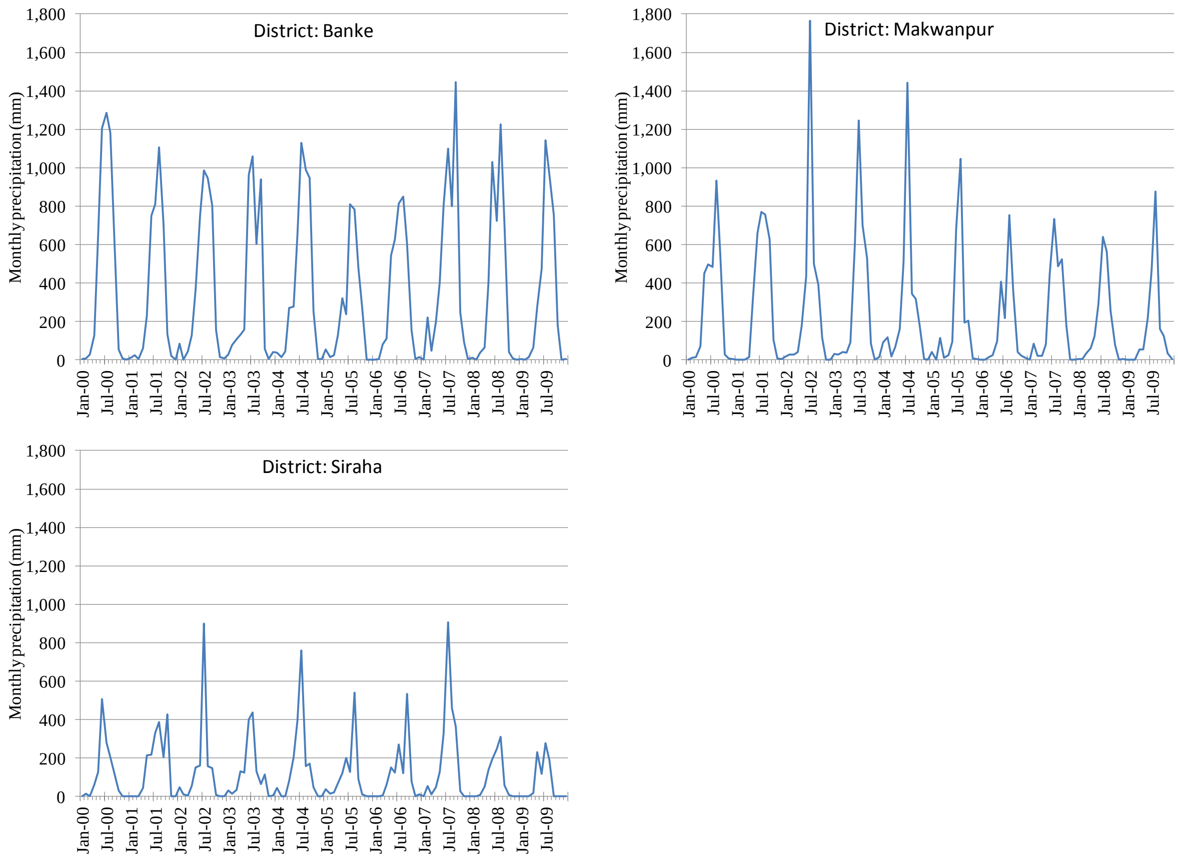
Another way of forecasting future precipitation relies on statistical inference. Given time-series precipitation data, the following simple autoregressive (AR) process is considered with deterministic periodicity taken into account:

$$y_t = \rho_0 + \sum_{s=1}^{m} \rho_s y_{t-s} + D_{\{month\}} + \varepsilon_t$$

$y_t$ is the amount of precipitation at period $t$. As shown above, the data clearly exhibit seasonality. This is adjusted by dummy variables for each month, $D_{\{month\}}$. With the seasonality adjusted, the data seem to be stationary. According to the Dickey-Fuller unit root test with 13 lags in the first differences, the null hypothesis of a unit root cannot be rejected in most cases. Therefore, the autoregressive model with 13 lags is applied for precipitation data in each district.[7] Then, the estimated AR models are used to compute one-step-ahead predictions for each project location. The predicted precipitation looks to much better fit the actual precipitation than the above simple backward-looking expectation. Many observations are mapped near the 45 degree line, meaning that the ratio of $Rain^a$ to $Rain^{eAR}$ is close to one (Figure 10).

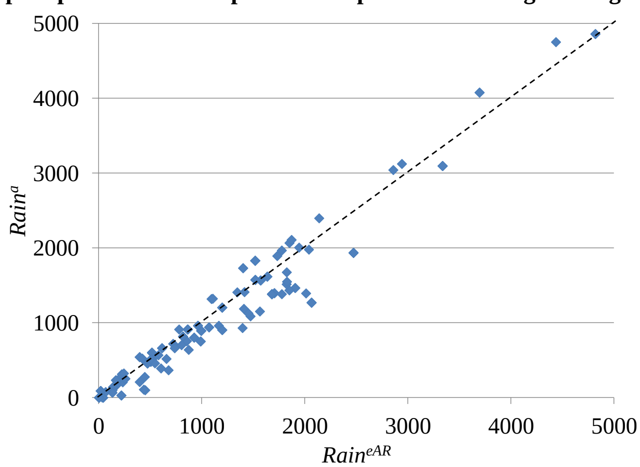
[6] The precipitation data the year before last are also used when the work schedule exceeds one year.
[7] The Dickey-Fuller unit root test results are shown in Appendix.

**Figure 9. Historical monthly precipitation data: Selected Districts**




Source: Author's calculation based on data from the Ministry of Environment, Nepal.

**Figure 10. Actual precipitation and AR-predicted expectations during the original work schedule**




Finally, in Equations (1) and (2), $X$ controls for contract-specific heterogeneity, such as length of roads (*length*) and amounts of materials used (*gravel*, *bitumen*, *cement*, etc.). To account for other district-specific unobservables, a set of dummy variables representing project location are included. The data contain 155 rural road contracts; the summary statistics are shown in Table 1. The size of road works is fairly small. The average cost estimate is about NRs8.7 million or $120,000 per contract. The works aim at upgrading an 8.7 km, single lane road on average. As discussed, precipitation is significant in Nepal. Each project has more than 1,000 mm precipitation during the project implementation. Of particular note, the actual precipitation is 24 percent more than the predicted one by looking back at the same period last year. The predicted values by the AR models fit better; it rains only 3 percent more than expected.

**Table 1. Summary statistics**

| Variable | Abbreviation | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Cost overrun rate (percent) | *overrun* | 155 | 3.7 | 6.3 | -14.8 | 21.7 |
| Project delay (days) | *delay* | 155 | 105.5 | 206.5 | -76.0 | 1217 |
| Actual precipitation during the original project period (mm) | $rain^a$ | 152 | 1092 | 974 | 0 | 4858 |
| Actual precipitation during the actual project period (mm) | $rain^t$ | 155 | 1652 | 1724 | 0 | 8774 |
| Precipitation during the original project period predicted by looking back (mm) | $rain^e$ | 153 | 1163 | 937 | 0 | 3771 |
| Precipitation during the original project period predicted by AR model (mm) | $rain^{eAR}$ | 145 | 1213 | 971 | 16 | 4819 |
| Memorandum items: | | | | | | |
| $rain^t / rain^a$ | | 146 | 2.56 | 4.13 | 0.00 | 23.40 |
| $rain^a / rain^e$ | | 146 | 1.24 | 1.81 | 0.17 | 19.06 |
| $rain^a / rain^{eAR}$ | | 145 | 1.03 | 0.71 | 0.14 | 5.62 |
| Engineering cost estimate (NRs million) | *cost* | 155 | 8.7 | 8.6 | 0.2 | 39.4 |
| Length of roads (km) | *length* | 155 | 7.4 | 5.0 | 0.2 | 34.0 |
| Number of lanes | *lane* | 155 | 1.0 | 0.2 | 1.0 | 2.0 |
| Thickness of road surface (mm) | *thickness* | 155 | 6.7 | 14.5 | 0 | 150.0 |
| Gravel (m3) | *gravel* | 155 | 2036 | 2497 | 0 | 18600 |
| Bitumen (kg) | *bitumen* | 155 | 3386 | 11942 | 0 | 79030 |
| Earthworks (m3) | *earth* | 155 | 7615 | 11622 | 0 | 93403 |
| Brickworks (m3) | *brick* | 155 | 62 | 161 | 0 | 1204 |
| Gabion (m3) | *gabion* | 155 | 241 | 742 | 0 | 8400 |
| Excavation (m3) | *excavation* | 155 | 2448 | 4840 | 0 | 29267 |
| Cement concrete (m3) | *cement* | 155 | 37 | 72 | 0 | 508 |
| Dummy variable for postqualification of bids | D(*postqualify*) | 155 | 0.9 | 0.3 | 0 | 1 |

## IV. MAIN ESTIMATION RESULTS AND POLICY IMPLICATIONS

The ordinary least squares (OLS) regression is performed for Equations (1) and (2), separately. First, with the actual precipitation data during the actual project period, it is shown that precipitation causes delays, but not cost overruns (Table 2).[8] The coefficient of $\ln Rain^{t}$ is estimated at 0.326, which is statistically significant in project delay equation. By contrast, the coefficient is not significant in the cost overrun equation. This is consistent to our prior expectations, because the sampled rural road works are fairly technically simple. Therefore, contractors are normally not allowed to claim for additional costs, unless there is a major change in specifications. On the other hand, when heavy rain or storms, regardless whether anticipated or not, happen, the contractors' likely response seems to be just to delay the project.

When the actual precipitation is decomposed into the three factors, it is found that the anticipated precipitation, $rain^{e}$, explains project delays. The coefficient is estimated at 0.493, which is statistically significant. It can be interpreted that if future precipitation were anticipated based on the backward-looking expectation, project delays could be avoided to a certain extent. The project delay is also explained by precipitation during the extended period. The coefficient is 1.633. In the cost overrun equation, none of the decomposed factors are statistically significant. Again, contractors are unlikely to claim for any cost adjustment because of weather in our case.

[8] In general there is a view that an additional incentive mechanism is needed particularly for large-scale projects, such as the midcourse review process where the contractual performance would be reviewed periodically and contractors would be penalized if they do not meet the intermediary targets. To tighten the contractor incentives and avoid ex post contract adjustments, the similar type of mechanism has been used in some of the road projects in Nepal in recent years.

**Table 2. OLS estimation results with backward-looking expectations**

| | Cost overrun | | | | Project delays | | | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| ln $rain^t$ | -0.316 | (0.265) | | | 0.326 | (0.150) ** | | |
| ln $rain^e$ | | | 0.069 | (0.578) | | | 0.493 | (0.294) * |
| ln $rain^a / rain^e$ | | | 0.392 | (1.043) | | | 0.051 | (0.333) |
| ln $rain^t / rain^a$ | | | 0.347 | (0.693) | | | 1.633 | (0.365) *** |
| ln *cost* | 0.945 | (0.755) | 0.723 | (0.815) | 1.449 | (0.297) *** | 1.235 | (0.285) *** |
| ln *length* | -1.899 | (0.687) *** | -1.793 | (0.771) ** | -0.851 | (0.312) *** | -0.849 | (0.287) *** |
| ln *lane* | 2.028 | (3.540) | 2.608 | (3.723) | 1.500 | (2.157) | 0.202 | (1.719) |
| ln *thickness* | -0.372 | (0.508) | -0.240 | (0.610) | -0.393 | (0.202) * | -0.495 | (0.181) *** |
| ln *gravel* | -0.038 | (0.203) | -0.144 | (0.278) | 0.022 | (0.116) | -0.094 | (0.139) |
| ln *bitumen* | 0.966 | (0.271) *** | 0.860 | (0.327) *** | -0.123 | (0.094) | -0.024 | (0.083) |
| ln *earth* | 0.505 | (0.250) ** | 0.567 | (0.279) ** | -0.262 | (0.105) ** | -0.248 | (0.099) ** |
| ln *brick* | 0.103 | (0.399) | 0.206 | (0.496) | 0.042 | (0.125) | -0.020 | (0.113) |
| ln *gabion* | -0.097 | (0.231) | -0.065 | (0.238) | -0.135 | (0.090) | -0.170 | (0.073) ** |
| ln *exavate* | -0.168 | (0.135) | -0.165 | (0.144) | 0.061 | (0.058) | 0.070 | (0.050) |
| ln *cement* | 0.049 | (0.240) | 0.033 | (0.257) | -0.280 | (0.096) *** | -0.160 | (0.075) ** |
| D(*postqualify*) | 4.056 | (2.070) ** | 6.001 | (2.488) ** | 0.474 | (0.846) | 0.717 | (0.611) |
| Constant | -13.976 | (8.553) * | -16.143 | (8.866) * | -17.007 | (3.405) *** | -14.836 | (3.090) *** |
| Obs. | 155 | | 145 | | 155 | | 145 | |
| R-squared | 0.540 | | 0.546 | | 0.562 | | 0.726 | |
| *F*-statistics | 9.29 | | 13.63 | | 12.91 | | 25.44 | |
| No. of dummy variables: | | | | | | | | |
| Project districts | 18 | | 18 | | 18 | | 18 | |

Note: Robust standard errors are shown in parentheses. *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

One might think that there may be potential correlation between cost overruns and project delays. In infrastructure projects, project delays often cause cost overruns. For instance, Flyvbjerg *et al*. (2004) shows that each year of delay would add on average $4.6 million to a project cost of $100 million in transport projects. To incorporate this possibility, the seemingly unrelated regression (SUR) model is performed, in which error terms are still assumed to be independent across auctions but have cross-equation correlation.

The result is shown in Table 3. The coefficients are the same as the OLS results, but the standard errors are more efficient. The SUR result confirms our main results: One of the significant determinants of project delays is anticipated precipitation. Regardless of whether anticipated or not, precipitation does not cause cost overruns. The correlation between the two equations is found significantly positive, as expected. The Breusch-Pagan test of independence can be rejected in both SURs. Thus, cost overruns and delays are likely interdependent on one another.

The autoregressive forecasting of precipitation has greater power to explain project delays than the simple backward-looking expectation. The precipitation predicted by the AR(13) process is used for $rain^{eAR}$, instead of $rain^{e}$. The estimation results are consistent to the above regardless of specification. The effect of $rain^{eAR}$ is found to be significant in both OLS and SUR models (Table 4). The estimated coefficient is greater than the estimation results with $rain^{e}$. This can be interpreted as gains from better expectations of precipitation. This impact is evident when the predicted impact of expected precipitation is netted from the total delays predicted. Many large delays would disappear when backward-looking expectations are used (Figure 11). With AR expectations, the distribution would become even more skewed toward zero; most of the observed delays could be explained by the precipitation predicted by the AR models.

In the case of cost overruns, there is no evident impact of predicting rainfall by the simple backward-looking expectation (Figure 12). However, the figure indicates that the AR prediction could help to explain cost overruns to a certain extent. The distribution clearly shifts towards the left, when the AR models are used. The average cost overrun rate would decline from 3.8 percent to 1.1 percent, although the statistical significance is still ambiguous. Hence, in general, better predictions of the climate, such as precipitation, is considered to help to avoid ex post contract amendments and manage public infrastructure procurement better.

**Table 3. SUR estimation results with backward-looking expectations**

| | SUR (1) | | | | SUR (2) | | | |
|---|---|---|---|---|---|---|---|---|
| | Cost overrun | | Project delays | | Cost overrun | | Project delays | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| ln $rain^t$ | -0.316 | (0.297) | 0.326 | (0.117) *** | | | | |
| ln $rain^e$ | | | | | 0.069 | (0.551) | 0.493 | (0.169) *** |
| ln $rain^a / rain^e$ | | | | | 0.392 | (0.936) | 0.051 | (0.288) |
| ln $rain^t / rain^a$ | | | | | 0.347 | (0.566) | 1.633 | (0.174) *** |
| ln *cost* | 0.945 | (0.758) | 1.449 | (0.298) *** | 0.723 | (0.818) | 1.235 | (0.251) *** |
| ln *length* | -1.899 | (0.644) *** | -0.851 | (0.254) *** | -1.793 | (0.668) *** | -0.849 | (0.205) *** |
| ln *lane* | 2.028 | (3.758) | 1.500 | (1.479) | 2.608 | (3.843) | 0.202 | (1.181) |
| ln *thickness* | -0.372 | (0.483) | -0.393 | (0.190) ** | -0.240 | (0.557) | -0.495 | (0.171) *** |
| ln *gravel* | -0.038 | (0.277) | 0.022 | (0.109) | -0.144 | (0.347) | -0.094 | (0.107) |
| ln *bitumen* | 0.966 | (0.218) *** | -0.123 | (0.086) | 0.860 | (0.261) *** | -0.024 | (0.080) |
| ln *earth* | 0.505 | (0.275) * | -0.262 | (0.108) ** | 0.567 | (0.301) * | -0.248 | (0.092) *** |
| ln *brick* | 0.103 | (0.304) | 0.042 | (0.120) | 0.206 | (0.359) | -0.020 | (0.110) |
| ln *gabion* | -0.097 | (0.195) | -0.135 | (0.077) * | -0.065 | (0.202) | -0.170 | (0.062) *** |
| ln *exavate* | -0.168 | (0.146) | 0.061 | (0.057) | -0.165 | (0.149) | 0.070 | (0.046) |
| ln *cement* | 0.049 | (0.234) | -0.280 | (0.092) *** | 0.033 | (0.249) | -0.160 | (0.076) ** |
| D(*postqualify*) | 4.056 | (1.812) ** | 0.474 | (0.713) | 6.001 | (2.072) *** | 0.717 | (0.637) |
| Constant | -13.976 | (8.664) | -17.007 | (3.410) *** | -16.143 | (9.170) * | -14.836 | (2.818) *** |
| Obs. | 155 | | 155 | | 145 | | 145 | |
| R-squared | 0.540 | | 0.562 | | 0.546 | | 0.726 | |
| Chi-2 | 182.20 | | 198.79 | | 174.20 | | 384.74 | |
| No. of dummy variables: | | | | | | | | |
| Project districts | 18 | | 18 | | 18 | | 18 | |
| Breusch-Pagan test of independence | 6.899 * | | | | 7.210 * | | | |

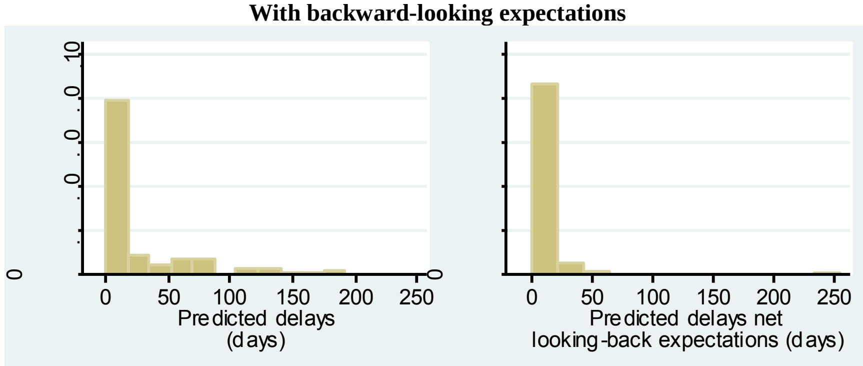
Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

**Table 4. OLS and SUR estimation results with precipitation predicted by AR models**

| | OLS | | | OLS | | | SUR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost overrun | | | Project delays | | | Cost overrun | | | Project delays | | |
| | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | |
| ln $rain^{eAR}$ | 0.415 | (0.767) | | 0.576 | (0.315) | * | 0.415 | (0.671) | | 0.576 | (0.208) | *** |
| ln $rain^{a}$ / $rain^{eAR}$ | -0.755 | (1.326) | | 0.141 | (0.469) | | -0.755 | (1.170) | | 0.141 | (0.363) | |
| ln $rain^{t}$ / $rain^{a}$ | 0.536 | (0.768) | | 1.646 | (0.357) | *** | 0.536 | (0.590) | | 1.646 | (0.183) | *** |
| ln *cost* | 0.824 | (0.806) | | 1.193 | (0.281) | *** | 0.824 | (0.811) | | 1.193 | (0.251) | *** |
| ln *length* | -1.902 | (0.810) | ** | -0.878 | (0.296) | *** | -1.902 | (0.678) | *** | -0.878 | (0.210) | *** |
| ln *lane* | 2.642 | (3.586) | | 0.263 | (1.710) | | 2.642 | (3.836) | | 0.263 | (1.189) | |
| ln *thickness* | -0.331 | (0.621) | | -0.514 | (0.184) | *** | -0.331 | (0.564) | | -0.514 | (0.175) | *** |
| ln *gravel* | -0.244 | (0.258) | | -0.042 | (0.142) | | -0.244 | (0.327) | | -0.042 | (0.101) | |
| ln *bitumen* | 0.960 | (0.373) | *** | -0.014 | (0.094) | | 0.960 | (0.278) | *** | -0.014 | (0.086) | |
| ln *earth* | 0.570 | (0.274) | ** | -0.269 | (0.100) | *** | 0.570 | (0.299) | * | -0.269 | (0.093) | *** |
| ln *brick* | 0.092 | (0.465) | | 0.010 | (0.107) | | 0.092 | (0.353) | | 0.010 | (0.109) | |
| ln *gabion* | -0.082 | (0.236) | | -0.172 | (0.071) | ** | -0.082 | (0.202) | | -0.172 | (0.063) | *** |
| ln *exavate* | -0.156 | (0.144) | | 0.076 | (0.049) | | -0.156 | (0.149) | | 0.076 | (0.046) | * |
| ln *cement* | 0.041 | (0.253) | | -0.164 | (0.073) | ** | 0.041 | (0.248) | | -0.164 | (0.077) | ** |
| D(*postqualify*) | 5.536 | (2.646) | ** | 0.712 | (0.630) | | 5.536 | (2.102) | *** | 0.712 | (0.652) | |
| Constant | -18.822 | (8.785) | ** | -15.069 | (3.090) | *** | -18.822 | (9.485) | ** | -15.069 | (2.941) | *** |
| Obs. | 145 | | | 145 | | | 145 | | | 145 | | |
| R-squared | 0.547 | | | 0.722 | | | 0.547 | | | 0.722 | | |
| *F*-statistic | 10.74 | | | 26.83 | | | | | | | | |
| Chi-2 | | | | | | | 175.35 | | | 377.38 | | |
| No. of dummy variables: | | | | | | | | | | | | |
| Project districts | 18 | | | 18 | | | 18 | | | 18 | | |
| Breusch-Pagan test of independence | | | | | | | 6.490 | ** | | | | |

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

**Figure 11. Impact of anticipating precipitation on project delays**
**With backward-looking expectations**




**With AR expectations**

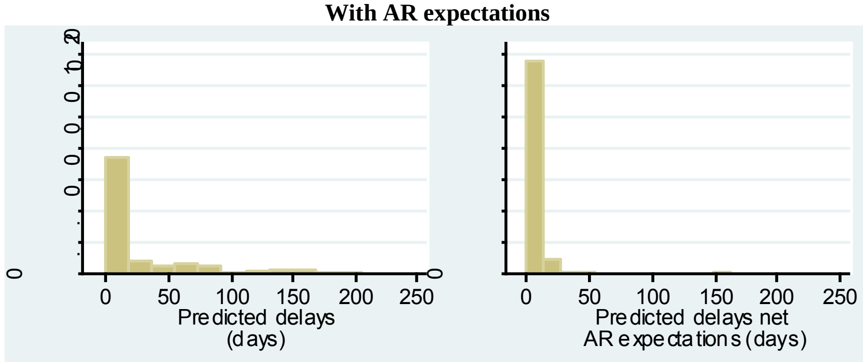
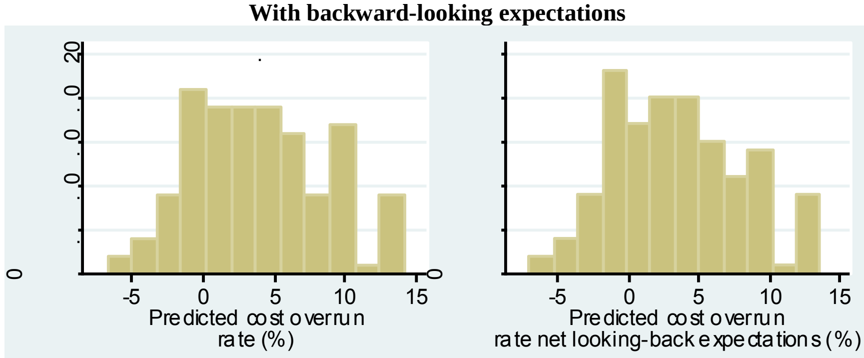
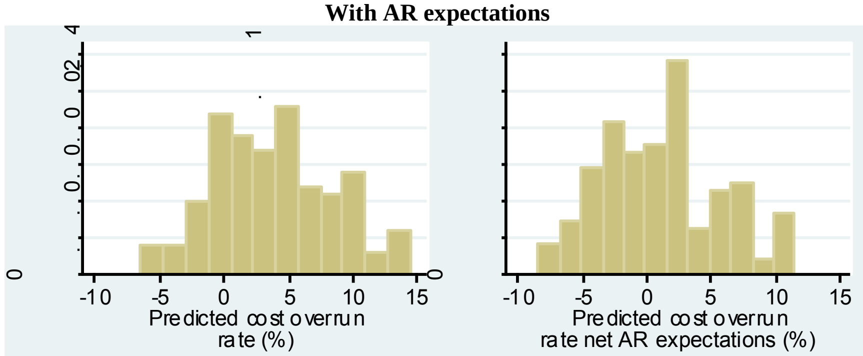



**Figure 12. Impact of anticipating precipitation on cost overruns**
**With backward-looking expectations**




**With AR expectations**



## V. Conclusion

It has been increasingly recognized that the climate is changing, which is creating various challenges to public infrastructure. Depending on the changing climate, technical standards and project specifications may have to be adjusted. However, it is less recognized that the procurement process of public infrastructure also needs to be adjusted. This paper examined a particular case of rural road procurement, which remains a significant challenge in many developing countries. Severe weather conditions, such as heavy rains and storms, are likely to interrupt civil works and wash away unpaved or gravel roads.

In general, ex post contract adjustments, such as cost overruns and project delays, have long been problems in public infrastructure procurement. Auction efficiency would be undermined, and the budgetary credibility would be ruined.

Using the procurement data from rural road projects in Nepal, the paper estimates the determinants of cost overruns and project delays, focusing on anticipated and unanticipated precipitation. It finds that precipitation causes delays, but not cost overruns. It also shows that even simple precipitation forecasts can have significant explanatory power for project delays, and cost overruns to a much lesser extent. If future precipitation were anticipated based on the backward-looking expectation, many massive delays could be avoided. If the autoregressive model were used, most of the observed delays could be avoided. The paper demonstrates a way of adapting public infrastructure procurement to the changing climate. Better climate forecasts can contribute to avoid unnecessary contract amendments and thus improve the predictability and efficiency in the budget formulation and execution.

## APPENDIX

**Table 5. Augmented Dickey-Fuller unit root tests**

| District | Obs. | Dickey-Fuller test statistic |
|---|---|---|
| Banke | 106 | -2.932 |
| Bardiya | 106 | -2.161 |
| Dhading | 106 | -3.454 ** |
| Dhanusa | 106 | -3.293 * |
| Kailali | 106 | -2.271 |
| Kapilvastu | 106 | -3.779 ** |
| Kaski | 106 | -2.870 |
| Mahottari | 106 | -1.616 |
| Makwanpur | 106 | -2.288 |
| Nawalparasi | 106 | -3.096 |
| Nuwakot | 106 | -2.906 |
| Palpa | 106 | -2.658 |
| Rautahat | 106 | -2.282 |
| Rupandehi | 106 | -5.423 *** |
| Salyan | 106 | -1.839 |
| Sarlahi | 106 | -1.939 |
| Siraha | 106 | -3.086 |
| Syangja | 106 | -2.781 |
| Udayapur | 106 | -3.439 * |

Note: *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

## REFERENCE


Alexeeva, Victoria, Gouthami Padam, and Cesar Queiroz. 2008. Monitoring road works contracts and unit costs for enhanced governance in Sub-Saharan Africa. Transport Papers TP-21, World Bank, Washington, DC.

Benamghar, Radia, Atsushi Iimi. 2011. Efficiency in public procurement in rural road projects of Nepal. World Bank Policy Research Working Paper No.5736. The World Bank: Washington DC.

Estache, Antonio, and Atsushi Iimi. 2011. *The Economics of Public Infrastructure Procurement in Developing Countries: Theory and Evidence.* Center of Economic Policy Research: London.

Flyvbjerg, Bent, Mette Skamris Holm, and Søren Buhl. 2002. Underestimating costs in public works projects: Error or lie? *Journal of the American Planning Association* 68: 279-295.

Flyvbjerg, Bent, Mette Skamris Holm, Søren Buhl. 2004. What causes cost overrun in transport infrastructure project? *Transport Review*, Vol. 24, pp. 3-18.

Guasch, Luis. 2004. *Granting and Renegotiating Infrastructure Concessions: Doing It Right*. Washington, DC: World Bank.

Nepal Central Bureau of Statistics. 2004. Nepal Living Standards Survey: Statistical Report. Nepal Central Bureau of Statistics.

Olken, Benjamin. 2007. Monitoring corruption: Evidence from a field experiment in Indonesia. *Journal of Political Economy* 115: 200-249.

Roberts, P., K. C. Shyam and C. Rastogi. 2006. Rural Access Index: a key development indicator. The World Bank Group, Transport Papers, TP10. The World Bank.

WHO and UNICEF. 2006. Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade. The World Health Organization and UNICEF.