What Drives the Dynamic Conditional Correlation of Foreign Exchange and Equity Returns?

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This paper establishes the link of microstructure and macroeconomic factors with the time-varying conditional correlation of foreign exchange and excess equity returns. By using the proposed DCC model with exogenous variables, capital flows and interest rate differentials are shown to be significant determinants of this correlation which is inclusive of the short-run variation of both asset returns. The results also provide evidence of the dynamic behavior of global investors as they seek parity in equity returns between home and foreign markets to reduce exchange rate risks.

Key words: uncovered equity parity, order flow, DCCX

1. Introduction

Short-run dynamics of nominal exchange rates are difficult to predict using macroeconomic models. Meese and Rogoff (1983a, 1983b) and Rogoff (2001) and the survey of the literature by Frankel and Rose (1995) have shown the failure of these models to capture the behavior of exchange rates in short horizons. However, the recent shift from macroeconomic to microstructure approach gave rise to more plausible models that can account for a large proportion of the variations in the movement of exchange rates. In microstructure models of exchange rates, Evans and Lyons (2002a, 2002b) revealed that order flow can explain 45% to 78% of the variation of the daily returns of the most liquid currencies. It is defined by Evans and Lyons (2002a) as a measure of buying and selling pressure or simply the difference between buyer-initiated and seller-initiated trade.

Related to order flow is the movement of equities across financial markets. Hau and Rey (2004) showed that equity flows have grown from 4% of GDP for 1975 in the United States (US) to 245% of the GDP in 2000 and argued that this movement in equity significantly influences the short-run dynamics of foreign exchange balances. In this interaction between equity and exchange rate, Brooks et al. (2001) observed that there is a negative correlation between foreign exchange return and *excess* equity return.

Hau and Rey (2006) referred this phenomenon of negative correlation as uncovered equity parity. They explained that home equity return in excess of foreign equity return corresponds to the depreciation of the home currency. The depreciation is driven by domestic purchases of foreign equities to reduce exchange rate risks. Under complete market assumption this risk can be hedged and eliminated but Levich, et al. (1999) found that only a small fraction of institutional investors actually hedge exchange rate risks so Hau and Rey (2004, 2006) concluded that although the foreign exchange market is very liquid there are limits to the foreign exchange arbitrage trading that investors may conduct in a complete market setting.

They also provided a plausible explanation to how equity and exchange returns relate to each other in integrated financial markets using portfolio shifts. Changes in asset allocation produce capital flows that find their way to the foreign exchange market. They also argued that exchange rates are primarily a function of investment flows resulting from limited forex arbitrage of risk-averse speculators. Furthermore, they posited that portfolio rebalancing moves the conditional correlation between equity and foreign exchange returns where the correlation structure between foreign exchange return and excess equity return is constant, although they did consider a structural change in the correlation between two periods.

In the new micro exchange rate economics using microstructure theory, Evans and Lyons (2002a) demonstrated that foreign exchange order flow and the exchange rate are not endogenous although both are simultaneously determined. They found that the innovations in the exchange rate are driven largely by order flow but not the other way. This phenomenon supports what they called pressure hypothesis where the causality goes from order flow to exchange rates. This observed dynamics are consistent with the theoretical models of Glosten and Milgrom (1985) and Kyle (1985) and the empirical investigation of Evans and Lyons (2002b, 2006), Payne (2003) and Froot and Ramadorai (2005) where order flows provide information about payoffs and they therefore drive prices.

Obstfeld and Rogoff (2000) have observed that fundamentals fail to explain the movement of exchange rates. However, Hau and Rey (2006) showed that correlation exists between foreign exchange return and capital flows while Evans and Lyons (2002a, 2006) used regression to show that order flows and interest rate differentials have significant impact to the foreign exchange return.

The dynamic conditional correlation (DCC) model of Engle (2002) and its extensions are widely used in the volatility literature and some of its applications in finance have been made by Manera, et al. (2006) on spot and forward oil price returns, Cappiello, et al. (2006) on international bond and equity returns, Billio et al. (2006) on sectoral asset allocation, Lanza et al. (2006) on oil forward and future prices, Vargas (2006) on exchange rate returns, Kuper and Lestano (2007) on stock markets and interest rates, among others. Incorporating exogenous variables in the DCC models is very important in evaluating potential determinants of time-varying conditional correlation between asset returns and this direction was suggested by Hafner and Franses (2003), Cappiello et al. (2006) and Feng (2006).

This paper has two main contributions. First, an extension of the DCC model is proposed by incorporating exogenous variables in the evolution of the time-varying correlation. And second, using this DCC model, it is shown that time-varying conditional correlation of the foreign exchange and excess equity returns varies across time and is driven by capital flows and interest rate differentials. The approach here differs largely from the problem currently being addressed in the literature, the modeling of the dynamics of foreign exchange returns. Typically regression is used to measure the impact of order flow on exchange rate returns like in Evans and Lyons (2002a) and Dunne et al. (2004), while this paper employs a conditional correlation model with exogenous variables to link the impact of two relevant variables on the time-varying correlation.

This paper is organized as follows. Section 2 presents the DCC model with exogenous variables. Section 3 specifies the time-varying correlation model of foreign exchange and excess equity returns. Section 4 discusses the data. Section 5 contains the results and discussion, and Section 6 concludes.

2. Asymmetric DCC Model with Exogenous Variables

The DCC model of Engle (2002) has the following specification. Let y_t be an $N \times 1$ vector of asset returns and $\Im_{t-1}$ a sigma algebra of information up to time $t-1$, without loss of generality μ_t is assumed to be zero, so

$$\begin{aligned} y_t &= \mu_t + \varepsilon_t \\ \varepsilon_t &= H_t^{1/2} u_t \text{ where } u_t \sim N(0, \mathrm{I}) \\ \varepsilon_t \mid \Im_{t-1} &\sim N(0, H_t). \end{aligned} \tag{1}$$

The conditional covariance matrix H_t can be expressed as a function of the DCC,

$$H_t = D_t R_t D_t = \left(\rho_{ij,t} \sqrt{h_{ii,t} h_{jj,t}}\right) \tag{2}$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}, \text{ where } Q_t^* = diag\left(\sqrt{q_{ii,t}}\right) \tag{3}$$

where Q_t evolves according to

$$\left(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B\right) + A'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')A + B'Q_{t-1}B\,. \tag{4}$$

This model was extended by Cappiello et al. (2006) to include asymmetric effects, that evolves according to

$$\left(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - \Gamma'\overline{N}\Gamma\right) + A'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')A + B'Q_{t-1}B + \Gamma'(n_{t-1}n_{t-1}{}')\Gamma \tag{5}$$

which is the Asymmetric DCC (ADCC) model.

Here $\varepsilon_t^{*} \sim N(0, R_t)$ is an $N \times 1$ vector of standardized residuals where $\varepsilon_{i,t}^{*} = \varepsilon_{i,t} h_{ii,t}^{-\frac{1}{2}}$ and $n_t = I\left(\varepsilon_t^{*} < \tau\right) \circ \varepsilon_t^{*}$ captures the asymmetric effects and where τ is typically set to zero. A, B and Γ are $N \times N$ diagonal matrices where $A = diag\left(\sqrt{\alpha}\right)$, $B = diag\left(\sqrt{\beta}\right)$ and $\Gamma = diag\left(\sqrt{\eta}\right)$. To ensure positive definiteness of Q_t it is assumed that α, β and η are non-negative coefficients satisfying $\alpha + \beta + \delta\eta < 1$ where δ is the maximum eigenvalue of $\overline{Q}^{-\frac{1}{2}}\left(\overline{N}\right)\overline{Q}^{-\frac{1}{2}}$ which was derived by Cappiello et al. (2006). Furthermore, $\hat{\overline{Q}} = T^{-1}\sum_{t=1}^{T}\varepsilon_t^{*}\varepsilon_t^{*}{}'$ and $\hat{\overline{N}} = T^{-1}\sum_{t=1}^{T} n_t n_t{}'$ serve as estimators of $\overline{Q}$ and $\overline{N}$, respectively.

In this paper, a model of ADCC which incorporates exogenous variables that drive the time-varying conditional covariance is proposed. Let X_t be a $p \times 1$ vector of exogenous variables, ξ be a $p \times 1$ vector of parameters and K be an $N \times N$ matrix that can either be an identity matrix or matrix of ones. The following specification for the proposed model has the following evolution of Q_t,

$$\left(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - \Gamma'\overline{N}\Gamma - K\xi'\overline{X}\right) + A'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')A + B'Q_{t-1}B + \Gamma'(n_{t-1}n_{t-1}{}')\Gamma + K\xi'X_{t-1} \tag{6}$$

which is called ADCCX, where $\hat{\overline{X}} = T^{-1}\sum_{t=1}^{T} X_t$ is the estimator of $\overline{X}$. It can be easily shown that the ADCCX regresses to a DCCX model if $\eta = 0$; to the ADCC model if $\xi = 0$; and, to the DCC model if $\eta = 0$ and $\xi = 0$.

To ensure the positive definiteness of Q_t, K is set as an identity matrix. It is further specified that $\xi' = \left(\xi_1 \quad \cdots \quad \xi_p\right)'$ where $\xi_k = \sqrt{\xi_k^{(k)}}$ be $\xi_k^{(k)} \in (0,1)$. This condition on ξ_k, however, might be very restrictive because it implies that the exogenous variables only drive the conditional variances $q_{ii,t}$ but not the conditional covariances $q_{ij,t}$ where $i \neq j$. However, since the conditional correlation $r_{ij,t}$ is equal to $q_{ij,t}\left(q_{ii,t}q_{jj,t}\right)^{-1/2}$, it is still indirectly a function of the exogenous variables. This restriction can be relaxed by setting K as a matrix of ones instead. Another concern about having $\xi_k = \sqrt{\xi_k^{(k)}}$ is that it restricts the sign of the parameters to be nonnegative. This is very limited and does not allow for the exogenous variable to have a negative impact on the conditional covariance Q_t. A remedy would be to allow ξ_k to take on a positive or negative value when K is an identity matrix provided that the positive definiteness of Q_t, $\forall t$ is not violated.

The maximum likelihood estimator of the ADCCX model is derived in the Appendix.

3. DCC Models of Foreign Exchange and Equity Returns

The indicator of uncovered equity parity is expected to be time-varying that is why a model that accounts for the variation in the correlation of foreign exchange and equity returns is necessary. This proposition is consistent with the dynamic behavior of investors when they react to changes in the economic environment by shifting their portfolio allocations between two markets. The ADCCX model in the previous section is used to model this time-varying correlation and is specified as follows. Let

$$R_t\left(-dE_t,\left(dS_t^{f*}-dS_t^{h}\right)\right)= f\left(Q_t\right) \tag{7}$$

where Q_t follows the evolution of the ADCCX model in Eq. (6) so that

$$\begin{aligned}&\overline{Q}-\mathrm{A}'\overline{Q}\mathrm{A}-\mathrm{B}'\overline{Q}\mathrm{B}-\Gamma'\overline{N}\Gamma-\mathrm{K}\xi_1\overline{dK}-\mathrm{K}\xi_2\overline{di}\\&+\mathrm{A}'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')\mathrm{A}+\mathrm{B}'Q_{t-1}\mathrm{B}+\Gamma'(n_{t-1}n_{t-1}{}')\Gamma+\mathrm{K}\xi_1\left(dK_{t-1}^{f}-dK_{t-1}^{h*}\right)+\mathrm{K}\xi_2 d\left(i_{t-1}^{f*}-i_{t-1}^{h}\right).\end{aligned} \tag{8}$$

Excess equity return is the difference between foreign and home log stock market index returns, $dS_t^{f*}-dS_t^{h}$. The foreign exchange return dE_t is the log return of E_t where E_t is in foreign currency per home currency so that foreign currency's appreciation against the home currency means $-dE_t>0$. Capital flows is the difference between the net foreign equity purchases by home residents and the net home equity purchases by foreigners, $dK_t^{f}-dK_t^{h*}$. Interest rate differential $i_t^{f*}-i_t^{h}$ is the difference between the foreign and home interest rates. The $\overline{dK}$ and $\overline{di}$ are equal to the mean of $dK_t^{f}-dK_t^{h*}$ and $d\left(i_t^{f*}-i_t^{h}\right)$, respectively. Alternative models ADCC, DCC and DCCX follow from Eq. (8) by setting the appropriate parameters to zero.

Following from the exogenous proposition about order flows by Evans and Lyons (2002a, 2006) and Froot and Ramadorai (2005), capital flows is taken as exogenous and the sign of the parameter ξ_1 is negative which indicates that capital flows move to satisfy the uncovered equity parity proposition by Hau and Rey (2006). Under the assumption of perfect price flexibility, the sign of the parameter ξ_2 is positive which implies that if the foreign interest rate rises it makes the foreign assets more attractive than before resulting in excess foreign equity return. However, the foreign currency depreciates in accordance with uncovered interest parity.

4. Data

The excess equity return, foreign exchange rate return, and capital flow data were sourced from the Princeton University website of Héléne Rey. The data included in this study are those of Germany and the United Kingdom (UK), considered the largest and most liquid equity and foreign exchange markets in Europe during the period under consideration, vis-à-vis the United States (US). The home country refers to the US. The data consists of monthly observations from January 1980 to December 2001 for a total of 264 observations.

In particular, $dS_t^{f*} - dS_t^h$ is the difference between the log foreign stock market index return and the log US stock market index return, $-dE_t > 0$ is the foreign currency's appreciation against the dollar, $dK_t^f - dK_t^{h*}$ is the difference between the net foreign equity purchases by US residents and the net US equity purchases by foreigners normalized by the average flows in the past 12 months, and $i_t^{f*} - i_t^h$ is defined as the difference between end-of-the-month yields of the foreign and US interest rates. With UK and the US the spread is the difference between 3-month T-bill yields which were downloaded from of the Bank of England and the US Federal Reserve websites, respectively. The interest differential between Germany and the US is derived from the 1-year T-bond yields, taken from EconStat.com.

5. Results and Discussion

The results begin with the GARCH(1,1) model of the returns. Table 1 suggests that foreign exchange returns exhibit heteroskedasticity based on the significant coefficients of the GARCH models. These show that the pound and the mark demonstrate persistency in the conditional variance even at the monthly returns. The volatility of excess equity returns is highly persistent for British equities while German equities display large short-run shocks.

The initial DCC models are given in Table 2, these are the ADCC models for both Germany and UK which indicate that there is no asymmetric effect between foreign exchange and excess equity returns since η is not significant. The absence of asymmetric effect implies that the magnitude of impact of either sign of the returns on the correlation does not significantly differ. This also suggests that a DCCX model is adequate for this purpose and Table 3 reports the parameter estimates of the four models without asymmetric effect arising from the special cases of Eq. (8)

The conditional correlation of foreign exchange and excess equity returns is highly persistent as shown by the significant parameter estimates of the DCC models and indicates that the correlation between the two is indeed time-varying for both markets. When only one of the exogenous variables is included in the model, $DCCX_{1A}$ and $DCCX_{1B}$, neither is significant. Both, however, are significant when they are in the model and the value of the parameter estimates change drastically which signals model misspecification when either variable is excluded. Although not reported here, the estimated asymmetric parameter of the ADCCX model is also not significant for both cases.

Table 1. GARCH(1,1) Models of Foreign Exchange and Excess Equity Returns

Parameters	Foreign Exchange Returns		Excess Equity Returns	
	Germany	UK	Germany	UK
$a_0^{\#}$	0.0010 (0.0010)	0.0002 (0.0002)	0.0230** (0.0095)	0.0022 (0.0018)
a_1	0.0214 (0.0340)	0.0696** (0.0338)	0.1707** (0.0833)	0.1266** (0.0577)
b_1	0.8853*** (0.1119)	0.9098*** (0.0398)	0.000 (0.2908)	0.7103*** (0.1607)

$a_0^{\#}$ is multiplied by a factor of 10

Table 2. ADCC Models of Foreign Exchange and Excess Equity Returns

	Germany	UK
α	0.0338 (0.0248)	0.0150 (0.0409)
β	0.9349*** (0.0569)	0.8790** (0.0810)
η	0.0105 (0.0524)	0.0986 (0.0710)
AIC	2.0066	2.0133
SIC	2.0473	2.0540
Log L	-260.86	-261.75

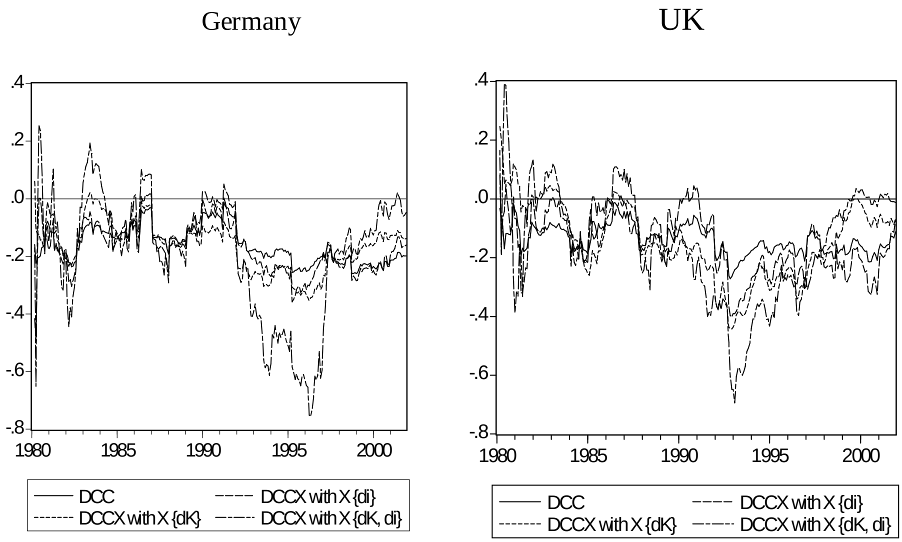
The sign of the parameter estimates of capital flows, ξ_1, is correct and is significant in both markets as shown by $DCCX_2$. For the UK market the loglikelihood ratio test between the DCC and the $DCCX_2$ model is significant at the 10% level and confirms the hypothesis in the literature that capital flows together with interest rate differentials significantly account for the short-run dynamics of foreign exchange and excess equity returns. Figure 1 present the graphs of the correlation.The graphs

Table 3. DCC and DCCX Models of Foreign Exchange and Excess Equity Returns

Parameters	Germany				UK			
	DCC	$DCCX_{1A}$	$DCCX_{1B}$	$DCCX_2$	DCC	$DCCX_{1A}$	$DCCX_{1B}$	$DCCX_2$
α	0.0160 (0.0287)	0.0174 (0.0224)	0.0257 (0.0240)	0.0350* (0.0187)	0.0207 (0.0444)	0.0174 (0.0324)	0.0411 (0.0451)	0.0009 (0.0337)
β	0.9518*** (0.0983)	0.9494*** (0.0450)	0.9212*** (0.0450)	0.9254*** (0.0307)	0.8943*** (0.1095)	0.9196*** (0.0461)	0.9141*** (0.1143)	0.9285*** (0.0465)
ξ_1	–	-0.0054 (0.0065)	–	-0.0151** (0.0065)	–	-0.0122 (0.0080)	–	-0.0163* (0.0088)
ξ_2	–	–	0.2209 (0.3833)	0.5203* (0.2781)	–	–	0.1909 (0.3004)	0.4834** (0.2135)
AIC	1.9932	2.0031	1.9999	2.0245	2.0073	2.0179	2.0080	1.9937
SIC	2.0203	2.0438	2.0407	2.0789	2.0345	2.0587	2.0487	2.0480
Log L	-260.10	-260.40	-259.99	-262.23	-261.96	-262.36	-261.05	-258.17

show that the inclusion of the exogenous variables clearly accentuates the negative correlation and confirms the time-varying nature of the uncovered equity parity.

Figure 1. DCC of the Mark (Pound) and the German (British) Excess Equity Returns v.v. the US

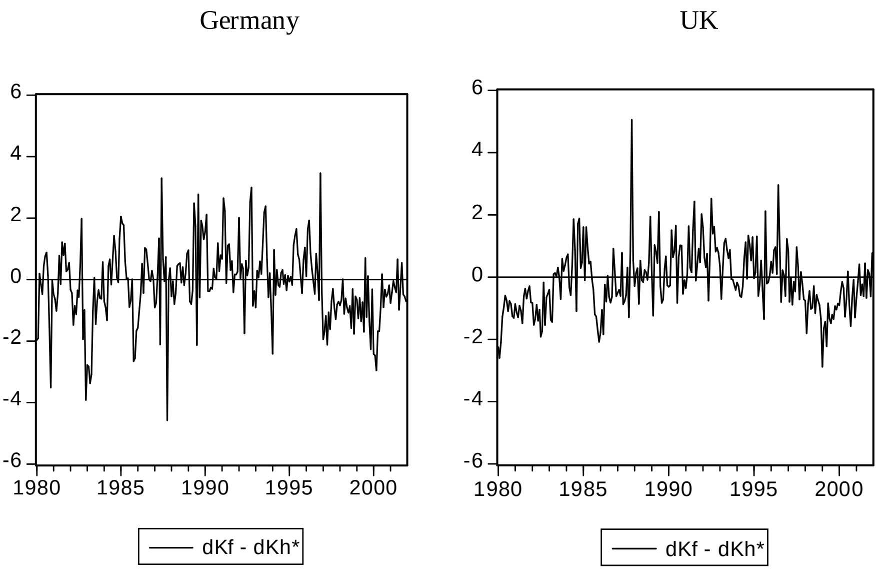


The outcome of this estimation shows that net capital flows from the home to the foreign market results in foreign currency appreciation that stabilizes the disparity in equity returns between the two markets when there is excess home equity return. This means that capital flows act to bring equity returns to parity to reduce the exchange rate risk involved when either equity markets have a higher return than the other through portfolio rebalancing according to Hau and Rey (2004).

The parameter estimate of ξ_2 is positive and correctly signed and also significant in both markets which confirms the result of Evans and Lyons (2002a, 2006). The relevance of interest rates, in which inflation and growth expectations are imbedded, argues for the impact of macroeconomic factors in driving this short-run dynamics of foreign exchange and equity returns.

Figures 2 shows the net capital flows where a positive value indicates a move in net capital towards Germany and UK, respectively, from the US. It is clear that when these graphs are superimposed to Figures 1, respectively, the negative correlations are observed when net capital flows are positive. And indeed, periods of heightened net capital outflow from the US result in higher magnitudes of negative correlation. Similarly, Figure 3 reveals that when German and UK interest rates exceed the US interest rates, especially, in periods of large positive differentials, the negative correlations are again observed to be correspondingly large.

Figure 2. Net Capital Flows of US Purchases of German (UK) Equities and German (UK) Purchases of US Equities

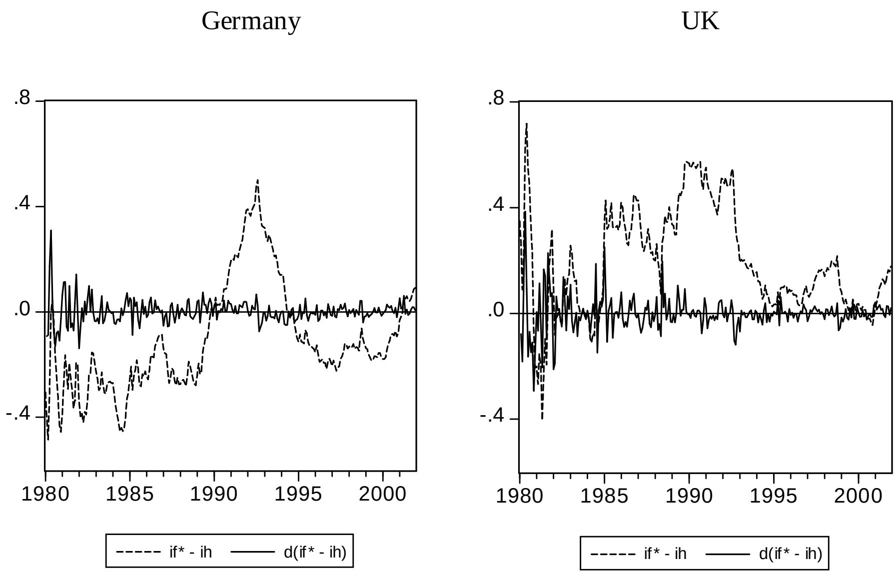


These results are evidence of the changing dynamics of investor behavior as they respond to varying risks in the two markets and they highlight the importance of equity return parity for global investors as they seek to minimize the variance of their portfolio holdings. This dynamics can be explained in the sense of the classic Markowitz's efficient frontier. The significance of the capital flows and interest rate differentials suggests that the correlation dynamics of foreign exchange and excess equity returns are subject to both microstructure and macroeconomic factors, at least in the sense of capital flows and interest rates, respectively.

6. Conclusion

The extension of the DCC model by incorporating exogenous variables is a natural direction to take in order to identify the factors that drive the time-varying conditional correlation of asset returns. By employing the DCC model, this paper shows that the correlation between foreign exchange and excess equity returns is time-varying. The DCCX model provides a convenient tool for characterizing this time-varying correlation as a function of capital flows and interest rate differentials.

Figure 3. Interest Rate Differential between Germany (UK) and the US, in percent



The optimizing behavior of global investors shows that they seek equity parity to minimize the foreign exchange risk in their portfolios. This paper demonstrates that this behavior results in capital flow movements that adjust both the exchange rate and equity returns in both home and foreign financial markets to satisfy uncovered equity parity. Capital flows contain information about investor decisions, in the microstructure context, and is significant in accounting for the time-varying conditional correlation of the foreign exchange and excess equity returns. This confirms that investor behavior is a rich source of information that can account for the short-run dynamics of foreign exchange rate. Furthermore, the interest rate differentials represent macroeconomic information that arguably drives this correlation as well. The results establish the link of microstructure and macroeconomic factors with the short-run dynamics of foreign exchange and equity returns.

APPENDIX

Maximum Likelihood Estimation of the ADCCX Model

The likelihood function under the assumption of multivariate normality of y_t is given by

$$L(\theta \mid y_t) = \prod_{t=1}^{T} \left[\frac{1}{\left(\sqrt{2\pi}\right)^N |H_t|^{1/2}} e^{-\frac{1}{2} y_t' H_t^{-1} y_t} \right].$$

Using the two-stage LIML procedure proposed by Engle (2002) the likelihood function is maximized with respect to two sets of parameters in succeeding steps.

The vector θ consists of GARCH parameters for each element of the N -dimensional y_t and the parameters of Q_t, where $y_t = \varepsilon_t$. Engle and Sheppard (2001) have shown the consistency and asymptotic normality of this two-stage procedure. The loglikelihood function is

$$\log L(\theta_1, \theta_2 \mid y_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(N \log(2\pi) + \log|H_t| + y_t' H_t^{-1} y_t \right)$$

$$= -\frac{1}{2} \sum_{t=1}^{T} \left(N \log(2\pi) + \log|R_t| + 2\log|D_t| + y_t' D_t^{-1} R_t^{-1} D_t^{-1} y_t \right)$$

where θ_1 consists of parameters of the MGARCH model, θ_2 consists of parameters of Q_t. Furthermore, $H_t = D_t R_t D_t$ and $D_t = diag\left(h_{11,t}^{1/2} \ldots h_{NN,t}^{1/2}\right)$. Engle and Sheppard (2001) set R_t as the identity matrix in the first stage estimation,

$$\log L(\theta_1 \mid y_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(N \log(2\pi) + \log|I_N| + 2\log|D_t| + y_t' D_t^{-1} I_N^{-1} D_t^{-1} y_t \right)$$

$$\hat{\theta}_1 = \arg\max[\log L(\theta_1 \mid y_t)]$$

which is equivalent to estimation of the univariate GARCH models of y_t.

The second stage estimation involves

$$\log L(\theta_2 \mid \hat{\theta}_1, y_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(N \log(2\pi) + \log|R_t| + 2\log|\hat{D}_t| + y_t' \hat{D}_t^{-1} R_t^{-1} \hat{D}_t^{-1} y_t \right)$$

where $\varepsilon_t^* = \hat{D}_t^{-1} y_t$. And since $R_t = Q_t^{*-1} Q_t Q_t^{*-1}$ where $Q_t^* = diag\left(\sqrt{q_{iit}}\right)$

$$\log L(\theta_2 \mid \hat{\theta}_1, y_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(N \log(2\pi) + \log|Q_t^{*-1} Q_t Q_t^{*-1}| + 2\log|\hat{D}_t| + \varepsilon_t^{*}{}' (Q_t^{*-1} Q_t Q_t^{*-1})^{-1} \dot{\varepsilon}_t^* \right)$$

The constant terms $N\log(2\pi)$ and $2\log|\hat{D}_t|$ are not necessary in the maximization and are dropped from the function so that

$$\log L'(\theta_2 \mid \hat{\theta}_1, y_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(\log|Q_t^{*-1} Q_t Q_t^{*-1}| + \varepsilon_t^{*}{}' (Q_t^{*-1} Q_t Q_t^{*-1})^{-1} \varepsilon_t^* \right)$$

$$\hat{\theta}_2 = \arg\max[\log L'(\theta_2 \mid \hat{\theta}_1, y_t)].$$

An expansion of the second stage loglikelihood function is

$$\log L'(\theta_2 \mid \hat{\theta}_1, y_t) = -\frac{1}{2}\sum_{t=1}^{T}\Big\{\log\Big|Q_t^{*-1}\Big(\tilde{Q} + \mathrm{A}'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')\mathrm{A} + \mathrm{B}'Q_{t-1}\mathrm{B} + \Gamma'(n_{t-1}n_{t-1}{}')\Gamma + \mathrm{K}\xi' X_{t-1}\Big)Q_t^{*-1}\Big|$$

$$+\varepsilon_t^{*\prime}\Big(Q_t^{*-1}\Big(\tilde{Q} + \mathrm{A}'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')\mathrm{A} + \mathrm{B}'Q_{t-1}\mathrm{B} + \Gamma'(n_{t-1}n_{t-1}{}')\Gamma + \mathrm{K}\xi' X_{t-1}\Big)Q_t^{*-1}\Big)^{-1}\varepsilon_t^{*}\Big\}$$

where

$$\tilde{Q} = \left(\overline{Q} - \mathrm{A}'\overline{Q}\mathrm{A} - \mathrm{B}'\overline{Q}\mathrm{B} - \Gamma'\overline{N}\Gamma - \mathrm{K}\xi'\,\overline{X}\right) \text{ and}$$

$$Q_t = \tilde{Q} + \mathrm{A}'(\varepsilon_{t-1}^{*}\varepsilon_{t-1}^{*}{}')\mathrm{A} + \mathrm{B}'Q_{t-1}\mathrm{B} + \Gamma'(n_{t-1}n_{t-1}{}')\Gamma + \mathrm{K}\xi' X_{t-1}.$$

The maximum likelihood estimators of ADCC, DCC and DCCX models can be derived by setting the appropriate parameters to zero.

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Spatial-Temporal Modeling of Growth in Rice Production in the Philippines

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When the strong El Nino episode in recent history happened in 1998, gross value added of the rice sector in the Philippines declined by as much as 24%, while other crops were able to keep the decline to within single digit level. The convergence hypothesis was verified among the Philippine provinces with reference to rice production. Convergence could mean harmonized efforts among various stakeholders to increase production and hopefully aim for food sufficiency. Divergence, on the other hand, could imply the need for structural assessment of the sector including the goals of various stakeholders, so that an optimal strategy that can stimulate development will be identified. A spatial term is incorporated into the model, providing empirical evidence for the need to localize rice production policy programs across the country. The spatial term also accounts for the natural endowments of the producing provinces that complement those policies in realizing progress in the sector. Rice production among the Philippine provinces diverged in the period 1990-2002. The El Niño episode of 1998 pulled down rice yield by as much as 10% aggravating further the divergence among provinces.

Keywords: *spatio-temporal model, backfitting, autoregression, convergence hypothesis, agricultural growth*

1. Introduction

From the 2003 estimates based on the Family Income and Expenditures Survey (FIES), 79% of agricultural households fall among the four lowest income deciles (bottom 40% of the population). The nonagricultural households however, only have 30% in the bottom 40% of the population. This is one of the many evidences of vulnerability of those in the agriculture sector not only in the Philippines, but in other developing countries as well. More specifically, within the agriculture sector, those engaged in crops are more disadvantageous with an average income in 2003 of P59,999 compared to the rest in the agriculture sector with an average income of P68,703.

The strong El Niño—a global weather anomaly whose effect to the Philippines is prolonged dryspell—episode of 1998 (NOAA 2007) expectedly affected the agriculture sector the most. The marginalization of the grains farmers, specifically, those planting rice can be gauged from the gross value added (GVA) of the rice sector that declined by as much as 24% while other crops were able to keep the decline to within single digit level. Although majority of agricultural land devoted to rice farming is now reached by irrigation systems—due to the often nonsustainable water source and physical infrastructure—rice farming still maintained the same marginalization due to the volatile weather conditions.

While the world is focusing on productivity growth to fuel agricultural growth, the Medium Term Philippine Development Plan 2004-2010 targets expansion of cultivation area as the source of agricultural growth for the Philippines. Expansion of production areas will only be secondary to a more important tool in policy making in Philippine agriculture – an assessment of the robustness of the sector to internal and external shocks. This assessment shall provide a good instrument in the development of policies and intervention strategies to avert the vulnerability of the rice sector.

The paper proposes a spatial-temporal model in the verification of the convergence hypothesis in rice production among Philippine provinces. The possible role of production area, corn production, and the El Niño phenomenon towards convergence/divergence among Philippine provinces are also explored. Specific focus on the assessment of the structural effect of events associated to the 1998 El Niño episode towards convergence in rice production in the Philippines is made. Rice production is highly vulnerable to weather perturbations hence, the focus on El Niño. Evidence of convergence will also be an evidence of equity among the stakeholders – that there is equity in the distribution of the needed intervention across the provinces, and that the present production areas are indeed suitable for rice production. This could also mean harmonized efforts among various stakeholders in the rice sector towards a common goal of food sufficiency at the least. Divergence, on the other hand, could mean that there is a need for a massive structural assessment of the sector and the goals of the different stakeholders to be able to identify an optimal strategy leading towards development.

2. Rice Production in Philippines

Patterns of rice production in the Philippines vary tremendously across provinces and over different periods. Rice is typically planted twice a year: one cycle during wet months, and one cycle during the dry months. Production cycle varies across provinces, the southern provinces usually planting ahead of the other provinces. In the period 1990-2002, quarterly growth (present quarter relative to same quarter of previous year) averaged 62% across all provinces. The yield has grown at an average of four percent per quarter. For the same reference period, the average yield is 2.78 metric tons per hectare (±0.81). Vulnerability of production to weather conditions is manifested in production area with average quarterly growth rate of 61% (negative for some provinces for certain quarters). Growth in production is the highest during the second quarter coming from a very low (no production in some provinces) production in the fourth and first quarter. Yield has been growing until a decline in 1998 (El Niño year), but it recovered shortly thereafter. Production exhibits similar average pattern across provinces per quarter. See Figures 1 and 2 for details.

Figure 1. Average Yield (metric tons/hectare/quarter) of Rice by Provinces

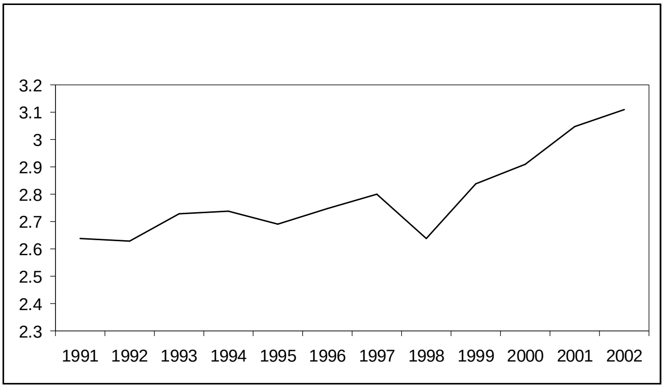
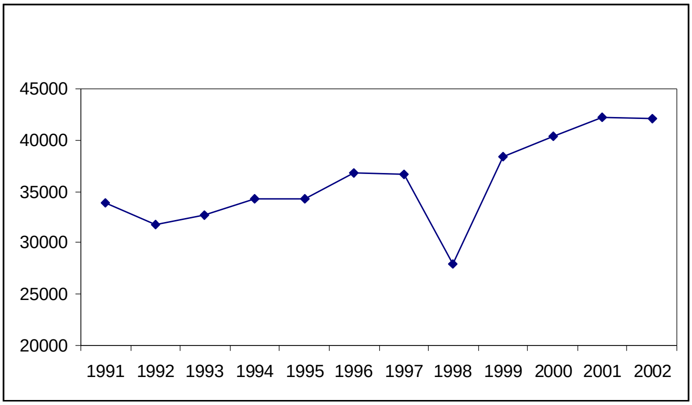


Figure 2. Average Rice Production (metric tons/quarter) by Provinces



3. Convergence and Agricultural Growth

Initially, sprouting from the Solow economic growth model, the concept of convergence has emerged from the literature for a relatively longer period now. As Di Liberto (2005) puts it, the Solow model predicts that economies converge to a steady state, where the key force that underlies the convergence effect is diminishing returns to reproducible capital. Furthermore, steady state growth rate is explained by the model and it is only possible to obtain continued growth in output per head if there is exogenous technical progress.

Several convergence models appear in the literature. As discussed by Barro and Sala-i-Martin (1992) and Sala-i-Martin (1996), there are initially two types of convergence: unconditional or absolute β-convergence and σ-convergence. If there is a tendency for poor economies to grow at a faster rate than the richer ones, then there is absolute β-convergence. Specifically, if $\beta > 0$ in the following regression equation $\gamma_{i,t,t+T} = \alpha - \beta \log(y_{i,t}) + \varepsilon_{i,t}$, where $\gamma_{i,t,t+T}$ is the annual growth rate of GDP of the i[th] economy between time t and t + T and $\log(y_{i,t})$ be the logarithm of the i[th] economy's GDP per capita at time t, then there is absolute β-convergence. On the other hand, if $\sigma_{t+T} < \sigma_t$, where σ_t is the standard deviation at time t of $\log(y_{i,t})$ across all economies, then the economies are converging. Thus, σ-convergence implies a decreasing trend in the dispersion of per capita GDP or income over time. It refers to the inter-temporal gradual development of the dispersion of world income. These two kinds of convergence are in a way related. Sala-i-Martin (1996) noted that β-convergence is a necessary but insufficient condition for sustained σ-convergence. Dela Fuente (2000) points out that convergence is necessary since the level of inequality will grow indefinitely when β is negative (i.e., when richer economies grow faster than the poorer economies).

Absolute convergence can only be expected or anticipated exclusively among economies which are structurally homogenous and the only difference across economies is in their initial levels of capital. This insight is instrumental in the conception of conditional convergence. This model allows for the differential determinants of the steady state levels (e.g. technological level, propensity to save, or population growth rate) of the economies under study. To verify existence of conditional convergence, one has to estimate the equation

$$\gamma_{i,t,t+T} = a - b\log(y_{i,t}) + \psi X_{i,t} + \varepsilon_{i,t,t+T}$$

where $X_{i,t}$ is a vector of variables that hold constant the steady state of economy i, and $b = (1 - e^{-\beta T})/T$. If the resulting β is positive for $X_{i,t}$ which is held constant, then there is conditional convergence. This seems to be a more realistic model since it is possible for economies to differ in varying technological and behavioral parameters which in turn translates to different levels of equilibrium.

Absolute convergence implies a tendency for differences in per capita income to wear off within the sample over time. In the long run, expected per capita income is the same for all members of the group, independently of its initial value. As explained by Dela Fuente (2000), this does not mean that inequality will disappear completely, for there will be random shocks with uneven effects on the different territories. Such disturbances, however, will only have transitory effects, implying that, in the long run, we should observe a fluid distribution in which the relative positions of the different regions change rapidly. With conditional β-convergence, on the other hand, each economy converges only to its own steady state but these can be very different from each other. Hence, a high degree of inequality could persist—even in the long run—and will be observed high persistence in the relative positions of the different economies. In other words, rich economies will generally remain rich while the poor continue to lag behind.

This leads us to the question of interpretability of the parameter β from the two models. β shows how fast the economies approach their steady state levels. It can help in the analysis of economic growth as it gives the rate or speed of convergence. Dela Fuente (2000) further noted that there is no contradiction between these estimates once it is recognized that they are measuring different things: while the unconditional parameter measures the overall intensity of a process of income convergence which may work in part through changes over time in various structural characteristics, the conditional parameter captures the speed at which the economy would be approaching a "pseudo steady state" whose location is determined by the current values of the conditioning variables.

Agriculture has a vital role to play in contributing to an economy's development. An implication of the model on structural transformation (Gollin et al. 2002) is that agricultural growth is central to development. The model actually shows a connection of agricultural growth to industrial development. Those countries which are experiencing increases in agricultural productivity will have a shift of workers from the agricultural to nonagricultural sector. They concluded that low agricultural productivity can substantially delay industrialization. This delay might result into low per capita income of the country compared to that of the leader. They further noted that a greater understanding of the determinants of agricultural productivity will improve our understanding of the development process among poor nations.

Ruttan (2002) cited that increases in agricultural production, both from crops and animals, initially were attributed to increases in the area cultivated but towards the end of the twentieth century, growth is coming from increases in land productivity – in output per hectare. Growth in total factor productivity in agriculture has made an important contribution to economic growth within rural areas and this has led to poverty reduction. There are several constraints on agricultural productivity: resource and environmental, scientific and technical, and institutional constraints. These will have differential effects on the economies having such constraints. Thus, specific actions can be taken on to facilitate growth in the economy.

4. Methodology

The paper uses quarterly rice production data aggregated at the provincial level for the period 1990 to 2002 in the Philippines. The data is collected from sample farming households by the Bureau of Agricultural Statistics (BAS) of the Department of Agriculture. Rice production is characterized by pronounced seasonality, having only two complete production cycles within a year.

A spatial autoregression term enriches the spatial-temporal growth model postulated as follows:

$$\Delta p_t = \beta_0 + \beta_1 \log(y_t) + \beta_2 \log(a_t) + \beta_3 \log(c_t)$$
$$+ \delta\left(\Delta p_t - \beta_0 - \beta_1 \log(y_t) - \beta_2 \log(a_t) - \beta_3 \log(c_t)\right) D_t + u + e_t$$
$$e_t = \rho e_{t-1} + z_t$$

Where Δp_t is a vector of growth rates in quarterly yield of rice for the provinces at time t, computed both from the original and the deseasonalized data. Deseasonalization is considered to eliminate the effect of strong seasonality in rice production since there are only two distinct cycles of rice production in the Philippines. It can also provide an alternative method of computing growth rates (quarter of the current year relative to the same quarter of the previous year). y_t is the vector of yield of rice for the provinces at time t, a_t is the vector of harvest area for rice, c_t is the vector of harvest area for corn, $D_t = \left[\left(d_{ij}^t\right)\right]$,

$$d_{ij}^t = \begin{cases} \frac{1}{m}, & \text{if province i and j are neighbors (in the same region)} \\ 0, & \text{otherwise} \end{cases}$$

a spatial autoregression indicator matrix, m is the number of provinces in a region, u a random effect component that will account for productivity endowments specific to the provinces and constant over time, e_t the vector of autocorrelated errors for the provinces at time t, and $z_t \sim N\left(0, \sigma^2\right)$. The effect of D_t is to average initial residuals of provinces in the same region. The residuals after accounting for the covariates are attributed to the spatial externalities common among provinces in the same region. The spatial externalities can serve as aggregate proximate indicators of the viability of the area in growing the crop (natural endowments) as well as policies and programs supporting rice production.

The model is estimated using a generalized least squares procedure in two backfitting steps similar to the one proposed by Landagan and Barrios (2007). Step 1 considers a linear model to compute the initial residuals. The residuals are then aggregated with D_t before the second generalized least squares is applied to the whole model with estimated residuals from Step 1. (See Landagan and Barrios 2007 for details of the estimation procedure.)

The effect of El Niño episode of 1998 is assessed by including a dummy variable in the model above, both as a location and scale parameter.

5. Results and Discussion

The random effect model with spatial-temporal autoregression for both the original data and the deseasonalized rice yield data significantly fits the provincial data (see Tables 1 and 2). Parameter estimates for both growth equations (original and deseasonalized) are similar. The possible effect of deseasonalization can be observed only in the magnitude of the spatial parameter.

Adjusting for spatial effect of the regions, the provinces failed to exhibit convergence in rice yield. This can be interpreted in two ways. First, the natural endowments of the provinces are distinctly varied. Even with interventions in farming systems and technological innovations, yield still vary significantly across the provinces in the same region. This means that the zoning of agricultural areas in the Philippines is an important strategy towards the identification of optimal production areas for certain crops, rice most specially. An intensive advocacy campaign among farmers to consider a crop more suitable to their soil is needed, and that rice is not really ideal for all provinces. The second interpretation of divergence is that, it is possible that the agricultural interventions are not tailor-fitted to the needs of the provinces benefiting from such.

The negative effect of area on growth in yield (declining returns to scale) is an indication that the newly developed production areas are not necessarily optimal for rice production. While many arable lands are still available in various parts of the country, it cannot be allocated for rice production. At least for the rice sector, expansion of harvest area seems not to provide support for growth. Corn production area does not significantly contribute to yield of rice. This means that either there is not enough crop rotation between rice and corn, or that rice and corn farmers do not give up production area for the other crops.

The autoregression parameter estimate is only 0.1014. This means that random shocks in yield in the previous quarter influences only about 10% of the random shocks in yield for the present quarter. This means that rice farming has become more intensive, that the present random shocks like technology application, soil, and weather endowments are usually inherited across neighboring quarters.

Table 1. Convergence in Quarterly Growth in Yield of Rice

Random Effect Model				
Overall Fit p-value	0.0000	Determinant	Coefficient	p-value
ρ	0.1014	Constant	-0.0462	0.166
σ_u	0.0327	Log(Yield)	0.1889	0.000
σ_ε	0.2243	Log(Area)	-0.0107	0.001
$\sigma_u/(\sigma_u + \sigma_\varepsilon)$	0.0208	Log(CornArea)	-0.0010	0.652
Random Effect Model Adjusted with Spatial Autoregression				
Overall Fit p-value	0.0000	Determinant	Coefficient	p-value
ρ	0.1014	Constant	-0.0503	0.134
σ_u	0.0347	Log(Yield)	0.2629	0.000
σ_ε	0.2216	Log(Area)	-0.0102	0.002
$\sigma_u/(\sigma_u + \sigma_\varepsilon)$	0.0239	Log(CornArea)	-0.0018	0.439
		Spatial Neighborhood	-1.6889	0.000

Table 2. Convergence in Quarterly Growth in Deseasonalized Yield of Rice

Random Effect Model				
Overall Fit p-value	0.0000	Determinant	Coefficient	p-value
ρ	-0.1557	Constant	-0.1376	0.000
σ_u	0.0294	Log(Yield)	0.2649	0.000
σ_ε	0.2108	Log(Area)	-0.0137	0.000
$\sigma_u/(\sigma_u + \sigma_\varepsilon)$	0.0190	Log(CornArea)	-0.0022	0.341
Random Effect Model Adjusted with Spatial Autoregression				
Overall Fit p-value	0.0000	Determinant	Coefficient	p-value
ρ	-0.1557	Constant	-0.1766	0.000
σ_u	0.0290	Log(Yield)	0.3285	0.000
σ_ε	0.2079	Log(Area)	-0.0130	0.000
$\sigma_u/(\sigma_u + \sigma_\varepsilon)$	0.0190	Log(CornArea)	-0.0022	0.318
		Spatial Neighborhood	-1.3433	0.000

The random effect due to the provinces accounts for a little more two percent of the aggregate of spatial and temporal variance (excluding the effect of the spatial parameter). This is an indication that spatial dependency is better accounted by the spatial autoregression component than by simply postulating a random component for the provinces. If the average residuals in a neighborhood are positive, then that is deducted (negative sign of coefficient) from the prediction of yield indicating that spatial externalities contributed negatively to yield. On the other hand, if the average initial residuals is negative, then the spatial externalities are meant to contribute positively to yield, hence the spatial effect is added accordingly.

The spatial externalities associated with a region includes, but not limited to, natural endowments due to ideal weather and soil fertility as well as the implementation of programs geared towards enhancing productivity. Majority of the regions yield positive effects for spatial externalities, with Central Luzon and Davao regions benefiting the most from spatial externalities. Davao region benefits from almost uniform distribution of rainfall throughout the year, in addition to the good quality of soil suited for grains production. Central Luzon, on the other hand, includes the most fertile land ideal for crop production (including rice). There are also the most advanced irrigation systems in the region complementing several demonstration farms of different agricultural research institutions. In 2002, of the 16 rice-producing regions, Central Luzon produced 17% of total rice production in the country. Three regions yield negative effect of spatial externalities, including ARMM, Central Visayas, and Eastern Visayas, where some of the lowest rice production can be observed in the period 1990-2002.

The 1998 El Niño episode contributed further in the divergence in rice yield among the provinces. The extent of the effect of drought varies across provinces. The coping mechanism adopted by the farmers to positively mitigate the ill-effects of the weather anomaly also varies across provinces, further spreading away rice yield. Provinces across the country generally experienced 10% reduction in yield as an effect of the drought. The El Niño episode of 1998 does not contribute significantly to the temporal variation as well as the provincial random effects.

6. Conclusion

A spatial-temporal autoregression model with random provincial effect is postulated to explain rice production growth in the Philippines. Growth rate is computed both from the original yield data as well as from the deseasonalized yield data. Parameter estimates for both growth equations (original and deseasonalized) are similar and the possible effect of deaseasonalization can be observed only in the magnitude of the spatial parameter.

Table 3. Convergence in Quarterly Growth in Yield of Rice (Effect of El Niño)

Random Effect Model

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1009	Constant	-0.0203	0.555
σ_u	0.0310	Y98	-0.0946	0.291
σ_ε	0.2230	Y98*Log(Yield)	-0.1011	0.025
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0190	Y98*Log(Area)	-0.0191	0.053
		Y98*Log(Corn Area)	0.0109	0.103
		Log(Yield)	0.1684	0.000
		Log(Area)	-0.0093	0.007
		Log(Corn Area)	-0.0024	0.304

Random Effect Model with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1009	Constant	-0.0160	0.644
σ_u	0.0331	Y98	-0.1097	0.216
σ_ε	0.2205	Y98*Log(Yield)	-0.0974	0.029
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0220	Y98*Log(Area)	-0.0102	0.107
		Y98*Log(Corn Area)	0.0102	0.124
		Log(Yield)	0.2414	0.000
		Log(Area)	-0.0094	0.007
		Log(Corn Area)	-0.0033	0.172
		Spatial Effect	-1.7289	0.000

Table 4. Convergence in Quarterly Growth in Yield of Rice (Effect of El Niño With Interaction on Spatial Autoregression)

Random Effect Model with Spatial Autoregression

		Determinant	Coefficient	p-value
Overall Fit p-value	0.0000			
ρ	0.1003	Constant	-0.0160	0.645
σ_u	0.0331	Y98	-0.1052	0.238
σ_ε	0.2205	Y98*Log(Yield)	-0.0838	0.116
$\sigma_u/(\sigma_u+\sigma_\varepsilon)$	0.0220	Y98*Log(Area)	-0.0163	0.098
		Y98*Log(Corn Area)	0.0104	0.117
		Log(Yield)	0.2425	0.000
		Log(Area)	-0.0094	0.007
		Log(Corn Area)	-0.0033	0.170
		Spatial Effect	-1.7515	0.000
		Y98* Spatial Effect	0.2745	0.645

Adjusting for spatial effect of the regions, the provinces failed to exhibit convergence in rice yield. The negative effect of area on growth in yield is an indication that the newly developed production areas are not necessarily optimal for rice production. While many arable lands are still available in various parts of the country, it cannot be allocated for rice production. At least for the rice sector, expansion of harvest area seems not to provide support for growth. Rice farming has become more intensive, that the present random shocks possibly caused by technology application, soil, and weather endowments are usually inherited across neighboring quarters.

A spatial term is incorporated into the model, providing empirical evidence for the need to localize rice production policy programs across the country. The spatial term accounts for the natural endowments of the producing provinces that complement those policies in realizing progress in the sector.

The 1998 El Niño episode contributed further in the divergence in rice yield among the provinces. The extent of the effect of the drought varies across provinces. The coping mechanism adopted by the farmers to positively mitigate the ill-effects of the weather anomaly also varies across provinces, further spreading away rice yield. Provinces across the country generally experienced 10% reduction in yield as an effect of the drought.

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Loglinear and Classification Tree Models of the Decision Paradigm of the Tuberculosis Diagnostic Committee

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The TB Diagnostic Committees (TBDC) evaluate cases of pulmonary tuberculosis (PTB) symptomatics who are smear-negative, but whose chest x-rays show lesions suggestive of tuberculosis that may warrant anti-TB treatment. In a review of the 600 TBDC referral forms of new patients who consulted in Manila district health centers from 2006 to 2008, the demographic and clinical characteristics associated with a positive chest x-ray and eventually leading to a diagnosis of new active PTB are identified using loglinear models and classification trees.

Hemoptysis is the most important variable in differentiating a TBDC decision of active PTB from non-PTB. The final loglinear model signifies that history of alcoholic beverage drinking, hemoptysis, weight loss, and age less than 40 are individually associated with a TBDC diagnosis of active PTB. Sex is used as the root node variable in the classification tree in order to improve classification accuracy and explore sex-related factor differences. In females, hemoptysis, alcoholic beverage drinking history, and age are individually associated with the target variable; while interactions among predictors of a diagnosis of active PTB are more demonstrable in males. The TBDC may find the proposed models useful as a decision tool in making a diagnosis of active pulmonary tuberculosis in support of the chest radiograph.

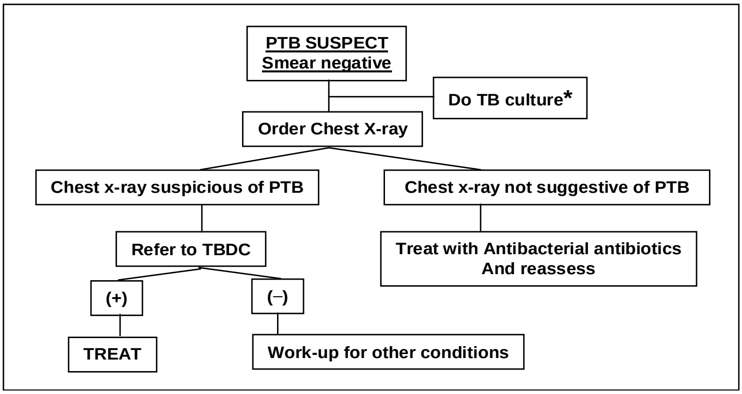
Keywords: *Classification tree, Loglinear model, Positive chest x-ray, Pulmonary tuberculosis, Sputum smear-negative, TB Diagnostic Committee*

1. Introduction

The Tuberculosis Diagnostic Committee (TBDC) evaluates cases of patients manifesting symptoms suggestive of pulmonary tuberculosis (PTB) but with negative sputum smears and suspicious chest radiograph results. The TBDC is composed of tuberculosis experts from the public and private sectors who represent various disciplines – a National Tuberculosis Program (NTP) coordinator, a radiologist, a clinician/internist often represented by a pulmonologist or an infectious disease specialist, and a NTP nurse who acts as the committee's secretary. The patients are referred by the health center physicians to the TBDC by sending all available chest x-ray films with the properly accomplished TBDC referral form. Upon review, the TBDC will deliberate and come up with a consensus based on the national guidelines (Figure 1) where patients requiring TB treatment shall avail of the directly observed treatment short-course or DOTS services provided by the health center (National Tuberculosis Control Program Manual of Procedures 2005).

In a setting where resources are crucial factors in health care decisions, the role of the TBDC is critical as it is the recommending authority in the option of which patient gets to be treated or not treated with antituberculosis drugs based on the patient's reported medical history, clinical findings and radiographic results. A quantitative characterization of the TBDC decision in terms of statistical models may give an objective description that would consequently facilitate in minimizing subjectivity in diagnosing a case or noncase of active pulmonary tuberculosis.

Figure 1. Diagnosis algorithm: Work-up of smear-negative PTB suspects. (Clinical practice guidelines for the diagnosis, treatment, prevention and control of tuberculosis in adult Filipinos: 2006 Update)



**TB culture Indications: Sputum TB culture with drug susceptibility testing is primarily recommended for those who are at risk for drug resistance and in smear-positive patients in all cases of – re-treatment, treatment failure, and in patients suspected to have one or multi-drug resistant TB (MDR-TB).*

The primary objective of the paper is to identify the demographic characteristics, medical history and physical examination findings that are associated with a positive chest x-ray and leading to a diagnosis of new active tuberculosis among sputum smear-negative patients referred to the TBDC.

2. Methodology

2.1 Study design, setting and subjects

This is a cross-sectional study of the TBDC referral forms of 600 patients who consulted in all 15 health centers of the first and second districts of Manila from 2006 to 2008. The inclusion criterion of the study is a patient who had been given the impression of being a new active TB case by the referring health center physician. A new patient is defined as one who had never had treatment for TB or, if with previous anti-TB medications, these were taken for less than four weeks. The reasons for exclusion of a subject upon review of his referral form are: a patient who had received any anti-TB drug for more than four weeks at any time and no specific TBDC recommendation (of prescribing antituberculosis treatment or no treatment) as in cases where the chest x-rays needed to be repeated due to poor quality films.

2.2 Study variables

In this study, the outcome variable is the diagnosis of new active PTB or “not PTB” by the TBDC among patients with negative sputum smears. The TBDC decision principally relates to their chest x-ray evaluation where the impression is negative or positive for PTB. A case of “no disease” in this study is represented by a negative result of the chest radiography leading to a TBDC diagnosis of inactive TB or other non-PTB lung disease where the recommendations for the patient are no anti-TB therapy, symptomatic treatment as needed and/or putting the patient under surveillance.

The independent variables taken into account as to their possible association with the TBDC diagnosis of a sputum smear-negative pulmonary tuberculosis are the demographic characteristics of the subjects such as age, sex, civil status, and job category. The variable dichotomies are male or female for sex, and single or not single (married/live-in and widow/separated) for civil status. Preliminary classification tree analysis was done to determine the dichotomous groupings of age (40 as cutoff) and job category (driver, student, or skilled worker against the other group of office/sales employee, service worker, professional, self-employed, Overseas Filipino worker (OFW), laborer/unskilled, or no occupation). The above groupings are used to construct loglinear models.

The medical history of the subjects is comprised of cough, sputum production, hemoptysis or coughing up blood, fever, weight loss, tiredness, chest/back pain, dyspnea or difficulty of breathing, exposure to a known PTB patient, any history of smoking, any history of alcoholic beverage drinking, co-existing disease, previous diagnosis or history of PTB, and intake of any anti-TB drugs. For the variable co-existing disease, the most recorded medical conditions of the subjects on the TBDC referral forms are bronchial asthma, diabetes mellitus, hypertension, heart disease, kidney disease, thyroid disease, and malignancy.

The pertinent physical examination findings based on patient records consist of emaciation (appearance of extreme wasting or thinness), pallor or paleness, and lung auscultation findings – namely, crackles or rales, decreased breath sounds, abnormal vocal fremitus, harsh breath sounds, rhonchi, and wheezes. The medical history and clinical features are categorized into the presence or absence of the condition. There are 26 independent variables under consideration in the study. To address the research question, loglinear models and classification trees are utilized to determine which of the 26 independent variables are associated, individually or in combination, with the TBDC diagnosis of sputum smear-negative tuberculosis.

Patient records were obtained upon approval of the Manila Health Department, the Division of Tuberculosis Control, the district offices and all the health centers of Manila Health Districts I and II. Prevention of redundant subject entries required the listing of patient identifiers during data collection. There is, however, no disclosure of identifiable patient information in any part of this research. Strict confidentiality in terms of data handling and record keeping is ascertained.

2.3 Univariate analysis

Univariate comparisons between smear-negative PTB and non-PTB patients as diagnosed by the TBDC are carried out using Student's t-test for the variable age, and the chi-square test for two independent samples for the rest of the predictors. Odds ratios (ORs) with 95% confidence intervals are calculated for each variable. Independent variables with chi-square p-values at or near 0.05 are prioritized for model building.

2.4 Loglinear model

The six variables which turned out significant in the univariate analyses are used to build loglinear models with TBDC diagnosis (T) as the variable of interest – these are any history of alcoholic beverage drinking (A), hemoptysis (H), job category (J), weight loss (W), any history of smoking (S), and age 40 (Y). Model building is done only on the seven variables since there was already overfitting (when the degrees of freedom already reaches zero and thus, no calculated likelihood ratio) upon fitting all four- and higher-factor terms. Likewise, the study objective to determine variables that would associate most with the TBDC diagnosis will be further underscored. Model selection by backward elimination is used by removing one term sequentially to determine which term would cause the least remarkable improvement in the model fit.

For a multidimensional contingency table with five variables, the expected number or frequency of cases in cell (i, j, k, l, m) is a function of all the variables in the model

$$\log \mu_{ijklm} = \lambda + \lambda_i^A + \lambda_j^H + \lambda_k^T + \lambda_l^W + \lambda_m^Y + \lambda_{ik}^{AT} + \lambda_{jk}^{HT} + \lambda_{kl}^{TW} + \lambda_{km}^{TY} + \lambda_{lm}^{WY}$$

where the log μ_{ijklm} is an additive function of the single-factor terms ($\lambda + \lambda_i^A + \lambda_j^H + \lambda_k^T + \lambda_l^W + \lambda_m^Y$) denoting the main effects and the two-factor interactions ($\lambda_{ik}^{AT} + \lambda_{jk}^{HT} + \lambda_{kl}^{TW} + \lambda_{km}^{TY} + \lambda_{lm}^{WY}$) representing partial associations. The superscripts are simply the labels for the variables namely: alcoholic beverage drinking (A), hemoptysis (H), TBDC diagnosis (T), weight loss (W), and age 40 (Y).

2.5 Classification tree

Classification trees are very flexible, conceptually simple, and can easily highlight interactions between the variables. Trees can also handle mixed variable types with consummate ease, and can cope with measurement vectors of different dimensionality from object to object, a property not possessed by all other classification methods (Breiman et al. 1984 and Hand 1997). Binary tree structured classifiers are created by repeated splits of subsets of the root node into two descendant subsets or nodes. Creating a classification tree is a series of determining the splits, deciding on a node to be terminal or proceed to splitting it, and assigning a class label to the terminal node. Mello et al. (2006), in a study in Rio de Janeiro, developed a prediction model for smear-negative pulmonary tuberculosis using logistic regression and classification and regression tree (CART) models where the patients' symptoms, physical signs and chest x-rays were the predictor variables.

2.6 Validation of loglinear and classification tree models

For both loglinear and classification tree analyses, model building is done with the training data (random 70% or 600 of the total 851 subjects) and then the model is validated using the test data (remaining 251 or 30% of the data). Two variables—job category and civil status—are with missing values. The training set has 12.67% (76 of 600) and 5.67% (34 of 600) missing values for job category and civil status, respectively. The test set has closely similar percentages at 13.55% (34 of 251) for job category and 5.58% (14 of 251) for civil status.

The univariate and loglinear analyses are conducted using the software SAS version 9.1. (Cary, NC: SAS Institute Inc). CART 6.2.0.160 PRO (San Diego, CA: Salford Systems) is used in the classification tree modeling.

3. Results and Discussion

3.1 Univariate analysis

There are 362 (60.33%) males and 238 (39.67%) females among the 600 study subjects. The mean age is 41.56 (± 17.87) where the age group 20–39 years old has the highest percentage of subjects at 40.83%, followed by the 40–59 age group at 30.67%. The rest of the subjects are 60 years old and above (19.17%) and below 20 years of age (9.33%).

Out of the 600 subjects, the TBDC gave a diagnosis of active PTB and recommended anti-TB treatment to 369 patients (61.50%); while 231 (38.50%) were negative for PTB. There is no significant difference (t-test p-value 0.1813) in the mean age of subjects diagnosed with PTB (age 40.79 ± 17.78) and those negative for PTB (age 42.80 ± 17.98). Utilizing chi-square test and odds ratios in Table 1, the resulting significant correlates at or near 0.05 level of a TBDC diagnosis of PTB are age below 40 (p-value = 0.0678), job categories of driver, student, or skilled worker (p-value = 0.0305), hemoptysis (p-value < 0.0001), weight loss (p-value = 0.0046), history of alcoholic beverage drinking (p-value = 0.0230), and history of smoking (p-value = 0.0243).

3.2 Loglinear modeling

Model fitting with the seven variables—TBDC diagnosis (T), any history of alcoholic beverage drinking (A), hemoptysis (H), job category (J), weight loss (W), any history of smoking (S), and age 40 (Y)—makes use of 524 observations from the training set since the variable job category (J) has missing values for 76 subjects. To maximize all 600 observations, modeling is likewise performed on the six variables (AHSTWY) and the five-factor term (AHTWY). Table 2 puts on view the goodness-of-fit tests and significant association terms for selected models under model groups (AHJSTWY), (AHSTWY), and (AHTWY).

Goodness-of-fit tests and residual analyses restricted the model selection to Model 8 ({AT}{HT}{TW}{TY}{WY}), Model 9 ({HT}{TW}{WY}{ATY}) and Model 10 ({HT}{TW}{WY}{AHY}{ATY}) under (AHTWY); mainly due to inclusion of significant terms relevant to the research objectives while exhibiting parsimony, and subsequently, good fit and least cell residuals. The chosen final loglinear model is Model {AT}{HT}{TW}{TY}{WY}, as shown in Table 2. Its simplicity and interpretability, as well as its consistently favorable performance for

Table 1. Demographic profile, medical history and clinical characteristics of the 600 study subjects

Predictor Variable	0 = No PTB / Inactive PTB (n=231)	1 = Active PTB (n=369)	Odds Ratio (95% CI)	Chi-square p-value
Demographic profile:				
Age*				
0 = Below 40 years old	105 (45.45)	196 (53.12)	0.74	0.0678*
1 = 40 years old and above	126 (54.55)	173 (46.88)	(0.53 – 1.02)	
Sex				
0 = Female	97 (41.99)	141 (38.21)	1.17	0.3571
1 = Male	134 (58.01)	228 (61.79)	(0.84 – 1.64)	
Civil status	(n=218)	(n=348)		
0 = Single	69 (31.65)	116 (33.33)	0.93	0.6780
1 = Married/Live-in, Widow/Separated	149 (68.35)	232 (66.67)	(0.65 – 1.33)	
Job Category*	(n=215)	(n=309)		
0 = No job, Office/ Sales/ Service worker, Professional, Self-employed, OFW, and Laborer/Unskilled	176 (81.86)	228 (73.79)	1.60 (1.04 – 2.46)	0.0305*
1 = Driver, Student, and Skilled worker	39 (18.14)	81 (26.21)		
Medical history:				
Cough				
0 = Absent	38 (16.45)	51 (13.82)	1.23	0.3780
1 = Present	193 (83.55)	318 (86.18)	(0.78 – 1.94)	
Sputum production				
0 = Absent	81 (35.06)	118 (31.98)	1.15	0.4346
1 = Present	150 (64.94)	251 (68.02)	(0.81 – 1.63)	
Hemoptysis*				
0 = Absent	207 (89.61)	274 (74.25)	2.99	<.0001*
1 = Present	24 (10.39)	95 (25.75)	(1.85 – 4.85)	
Fever				
0 = Absent	154 (66.67)	230 (62.33)	1.21	0.2816
1 = Present	77 (33.33)	139 (37.67)	(0.86 – 1.71)	
Weight loss*				
0 = Absent	118 (51.08)	145 (39.30)	1.61	0.0046*
1 = Present	113 (48.92)	224 (60.70)	(1.16 – 2.25)	
Tiredness				
0 = Absent	106 (45.89)	158 (42.82)	1.13	0.4612
1 = Present	125 (54.11)	211 (57.18)	(0.81 – 1.58)	
Chest pain/Back pain				
0 = Absent	76 (32.90)	121 (32.79)	1.00	0.9779
1 = Present	155 (67.10)	248 (67.21)	(0.71 – 1.43)	
Dyspnea				
0 = Absent	137 (59.31)	215 (58.27)	1.04	0.8009
1 = Present	94 (40.69)	154 (41.73)	(0.75 – 1.47)	

Predictor Variable	0 = No PTB / Inactive PTB (n=231)	1 = Active PTB (n=369)	Odds Ratio (95% CI)	Chi-square p-value
TB Exposure				
0 = Absent	174 (75.32)	284 (76.96)	0.91	0.6456
1 = Present	57 (24.68)	85 (23.04)	(0.62 – 1.34)	
Any History of Smoking*				
0 = Absent	157 (67.97)	217 (58.81)	1.49	0.0243*
1 = Present	74 (32.03)	152 (41.19)	(1.05 – 2.10)	
Any History of Alcoholic Beverage Drinking*				
0 = Absent	205 (88.74)	302 (81.84)	1.75	0.0230*
1 = Present	26 (11.26)	67 (18.16)	(1.08 – 2.85)	
Co-existing Disease				
0 = Absent	212 (91.77)	331 (89.70)	1.28	0.3994
1 = Present	19 (8.23)	38 (10.30)	(0.71 – 2.28)	
History of PTB				
0 = Absent	196 (84.85)	312 (84.55)	1.02	0.9221
1 = Present	35 (15.15)	57 (15.45)	(0.65 – 1.62)	
Intake of any anti-TB drugs				
0 = Absent	199 (86.15)	313 (84.82)	1.11	0.6557
1 = Present	32 (13.85)	56 (15.18)	(0.70 – 1.78)	
Physical examination (P.E.):				
Specific P.E. Findings:				
Emaciation				
0 = Absent	223 (96.54)	363 (98.37)	0.46	0.1469
1 = Present	8 (3.46)	6 (1.63)	(0.16 – 1.35)	
Pallor				
0 = Absent	219 (94.81)	357 (96.75)	0.61	0.2373
1 = Present	12 (5.19)	12 (3.25)	(0.27 – 1.39)	
Crackles or Rales				
0 = Absent	204 (88.31)	319 (86.45)	1.1843	0.5070
1 = Present	27 (11.69)	50 (13.55)	(0.72 – 1.95)	
Decreased Breath Sounds				
0 = Absent	203 (87.88)	311 (84.28)	1.35	0.2211
1 = Present	28 (12.12)	58 (15.72)	(0.83 – 2.20)	
Vocal Fremitus				
0 = Absent	225 (97.40)	366 (99.19)	0.3074	0.0802
1 = Present	6 (2.60)	3 (0.81)	(0.08 – 1.24)	
Harsh Breath Sounds				
0 = Absent	201 (87.01)	317 (85.91)	1.0991	0.7014
1 = Present	30 (12.99)	52 (14.09)	(0.68 – 1.78)	
Rhonchi				
0 = Absent	212 (91.77)	349 (94.58)	0.6394	0.1750
1 = Present	19 (8.23)	20 (5.42)	(0.33 – 1.23)	
Wheeze				
0 = Absent	221 (95.67)	356 (96.48)	0.8070	0.6168
1 = Present	10 (4.33)	13 (3.52)	(0.35 – 1.87)	

Table 2. Goodness-of-fit tests and significant parameters for selected loglinear models with variables TBDC decision[a] (T), any history of alcoholic beverage drinking[b] (A), hemoptysis[c] (H), job category[d] (J), any history of smoking[e] (S), weight loss[f] (W), and age[g] (Y).

A. Loglinear model group (AHJSTWY) n=524	*df*	Likelihood Ratio (G^2)	p-value	Chi-square	Significant Association at 0.05
1) {AS}{AT}{HT}{JT}{JY}{SW}{TW}{TY}	71	78.24	0.2598	83.18	AS, HT, JY, SW, TW, TY at 0.0564
2) {AS}{HT}{JY}{SW}{TW}{TY}	73	81.41	0.2339	85.90	AS, HT, JY, SW, TW, TY
B. Loglinear model group (AHSTWY) n=600	*df*	Likelihood Ratio (G^2)	p-value	Chi-square	Significant Association at 0.05
3) {AS}{AT}{HT}{SW}{SY}{TW}{TY}{WY}	39	39.84	0.4324	42.06	AS, HT, SW, SY, TW, TY, WY
4) {AS}{HT}{SW}{SY}{TW}{TY}{WY}	40	41.68	0.3974	44.53	AS, HT, SW, SY, TW, TY, WY
5) {AS}{HT}{SW}{TW}{TY}{WY}	41	49.15	0.1791	54.12	AS, HT, SW, TW, WY, TY at 0.0594
C. Loglinear model group (AHTWY) n=600	*df*	Likelihood Ratio (G^2)	p-value	Chi-square	Significant Association at 0.05
6) {AH}{AT}{HT}{TW}{TY}{WY}	18	22.25	0.2210	21.63	AH, HT, TW, TY, WY
7) {AH}{HT}{TW}{TY}{WY}	19	24.48	0.1785	23.79	AH, HT, TW, TY, WY
†8) {AT}{HT}{TW}{TY}{WY}	19	27.45	0.0947	28.76	AT, HT, TW, TY, WY
9) {HT}{TW}{WY}{ATY}	17	24.09	0.1170	25.36	AT, HT, TW, TY, WY
10) {HT}{TW}{WY}{AHY}{ATY}	14	15.17	0.3666	14.76	AY, HT, TW, TY, WY, AHY, ATY, AT at 0.0563

† Chosen final loglinear model
[a] where 0=Non-PTB and 1=Active PTB
[b] where 0=Absent and 1=Present
[c] where 0=Absent and 1=Present
[d] where 0=No job, Office/Sales employee, Service worker, Professional, Self-employed, Overseas worker, Laborer/Unskilled and 1=Driver, Student, Skilled worker;
[e] where 0=Absent and 1=Present
[f] where 0=Absent and 1=Present
[g] where 0=Below 40 years old and 1=40 years old & above

Table 3. Estimated odds ratios for Loglinear model {AT}{HT}{TW}{TY}{WY} with variables TBDC decision[a] (T), any history of alcoholic beverage drinking[b] (A), hemoptysis[c] (H), weight loss[d] (W), and age[e] (Y)

Association Term	Odds Ratio (95% CI)
AT	1.662 (1.021 - 2.704)
HT	2.829 (1.745 - 4.587)
TW	1.743 (1.24 - 2.451)
TY	0.672 (0.478 - 0.944)
WY	2.155 (1.544 - 3.007)

[a] *where 0=Non-PTB and 1=Active PTB*
[b, c, d] *where 0=Absent and 1=Present*
[e] *where 0=Below 40 years old and 1=40 years old & above*

both the design and test sets, render the model the best to represent and characterize our data.

The calculated fitted odds ratios for the final model {AT}{HT}{TW}{TY}{WY} are in Table 3. In the interpretation of the estimated odds ratios, among sputum smear-negative patients referred to the TBDC –

For AT: A diagnosis of active pulmonary tuberculosis is 1.66 (95% CI: 1.02, 2.70) times as likely for those with history of alcoholic beverage drinking as for those without alcoholic beverage drinking history.

For HT: A diagnosis of active PTB is 2.83 (95% CI: 1.74, 4.59) or almost 3 times as likely for those with symptom of hemoptysis as for those without hemoptysis.

The TW odds ratio of 1.74 (95% CI: 1.24, 2.45) means the odds of a diagnosis of active PTB are 1.74 times greater for those with weight loss than for those without symptom of weight loss.

For TY: With an odds ratio of 0.67 (95% CI: 0.48, 0.94), the interpretation of the reciprocal odds ratio is that the odds of a diagnosis of active PTB are 1.49 (95% CI: 1.0597, 2.09154) or about one-and-a-half times greater for those below 40 years of age than for those 40 years old and above.

For WY: Those who are 40 years old and above are 2.16 (95% CI: 1.54, 3.00) times as likely to have symptom of weight loss as for those below 40 years of age.

The interpretation of Model {AT}{HT}{TW}{TY}{WY} is the variables history of alcoholic beverage drinking (A), hemoptysis (H), weight loss (W), and age (Y) are individually associated with a TBDC diagnosis of active PTB (T); and there is an interaction between weight loss (W) and age (Y).

3.3 Classification tree

In the analysis using classification trees, age is entered as a continuous variable, while civil status and job category are multi-categorized into their natural groupings. Resulting from the initial tree fitting using all 26 predictors, six variables that are the leading root node splitters—hemoptysis (H), weight loss (W), history of alcoholic beverage drinking (A), job category (J), history of smoking (S), and age (Y)—are maintained to grow another set of trees. All possible combinations of the six predictors are forced into the tree via the root node and its left and the right child nodes to search for appropriate trees.

Sex is subsequently added to the six variables in order to improve the classification accuracy of the model tree and explore differences in the sex-related factors, even if it is not individually associated with the TBDC decision. In profiling subjects by sex for both training and test data, the chi-square test shows females have significantly higher percentages of nonsingles (p-value = 0.0353), with medical history of TB exposure (p-value = 0.05) and co-existing disease (p-value = 0.0429). A significant majority of males exhibit the characteristics: job=1 or driver, student, or skilled worker (p-value < 0.0001); and with histories of smoking (p-value < 0.0001) and alcoholic beverage drinking (p-value < 0.0001). Thus, differences in the splitter characteristics between male and female subjects may well be highlighted when sex is forced as the root node variable.

In a summarized evaluation of the four best performing trees in Table 4 from about 150 generated classification trees, results of the test data are likewise listed since they are considered as the fair estimates of the tree performance since the training sample is the one actually used in building the model. Majority of the most favorable criteria in both training and test data is observed for Tree 47. These are comparatively higher (or highest) values of prediction accuracy (64.14 – 64.47), ROC score (0.66 – 0.69), sensitivity (0.62 – 0.63), and specificity (0.65 – 0.69); together with lower misclassification rates (30.74 – 38.21) and relative cost (0.71).

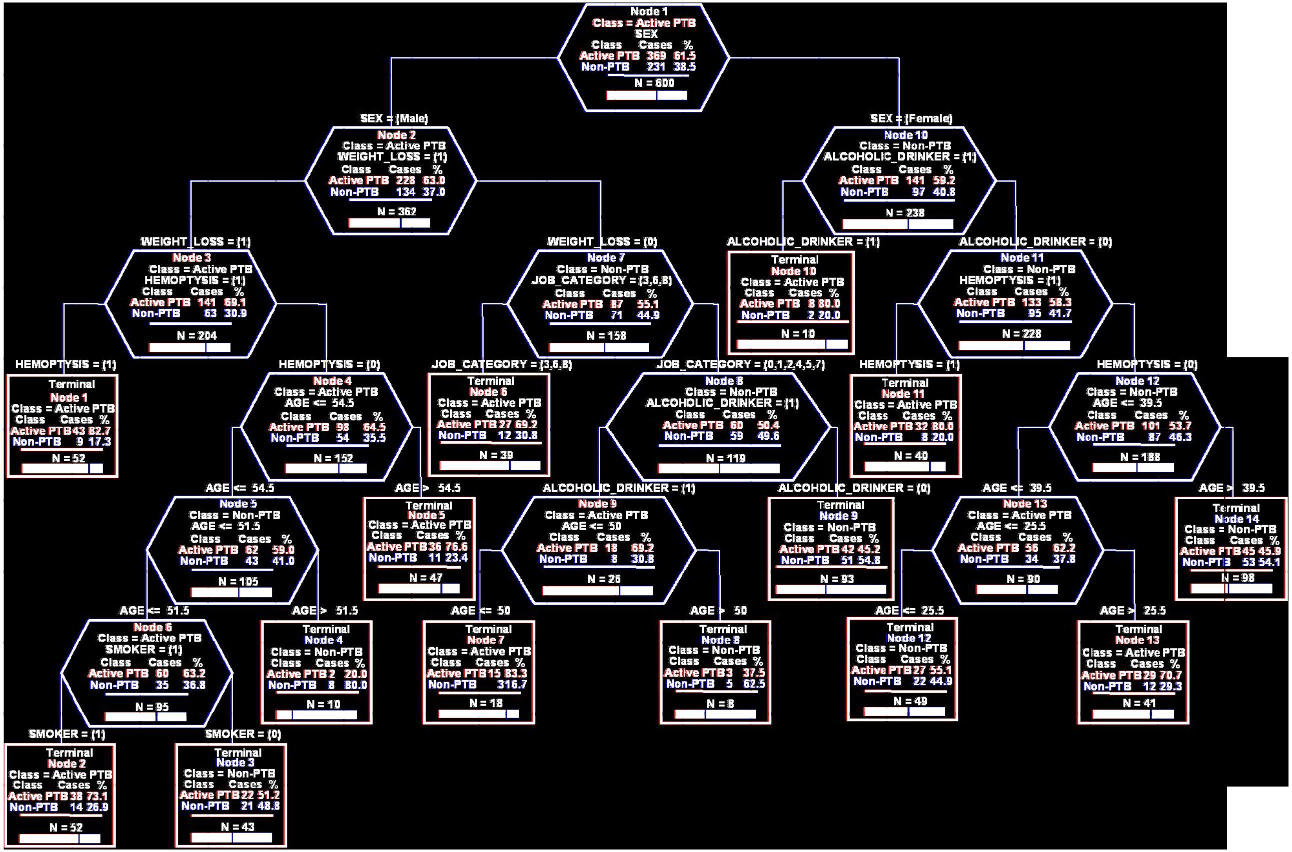
Based on the aforementioned reasons, Tree 47 (with root node=sex, left node=weight loss, right node=alcoholic beverage drinking history) is considered as the most accurate classification tree for the study. The illustration of our selected classification tree is in Figure 2. Even if hemoptysis is suppressed from being in one of the top nodes, it persists to show strong relations with the target variable by appearing in both sides of the tree or for both sexes. Nodes ending with presence of hemoptysis (H=1) capture high percentages of the active PTB cases, namely, 82.7% in terminal node 1 and 80% in terminal node 11.

Table 4. Evaluation criteria of candidate classification trees with TBDC decision (T) as the target variable and predictors sex, history of alcoholic beverage drinking (A), hemoptysis (H), job category (J), history of smoking (S), weight loss (W), and age (Y).

MODEL TREE	ROOT NODE	LEFT CHILD	RIGHT CHILD	Training Data (n=600)						Test Data (n=251)								
				Prediction Accuracy	Misclas-sification Rate for T=1	Misclas-sification Rate for T=0	ROC	Sensi-tivity	Speci-ficity	Prediction Accuracy	Misclas-sification Rate for T=1	Misclas-sification Rate for T=0	ROC	Sensi-tivity	Speci-ficity	Number of Nodes	Relative Cost	Variables in the Tree
23	W	H	S	65.67[b]	32.79	36.80	0.70	0.67	0.63	59.76[w]	37.41	44.23[w]	0.59[w]	0.63	0.56[w]	13	0.82[w]	AHJSWY
39	Sex	H	Y	62.67[w]	38.21[w]	35.93	0.65[w]	0.62[w]	0.64	62.15	39.46[w]	35.58	0.63	0.61[w]	0.64	9	0.75	HJSWY+Sex
†47	Sex	W	A	64.67	38.21[w]	30.74[b]	0.69	0.62[w]	0.69	64.14[b]	36.73	34.62[b]	0.66[b]	0.63	.065[b]	14	0.71[b]	AHJSWY+Sex
51	Sex	W	Y	65.33	31.71[b]	39.39[w]	0.76	0.68[b]	0.61[w]	63.35	34.69[b]	39.42	0.64	0.65[b]	0.61	12	0.74	AHJSWY+Sex
Minimum value				62.67	31.71	30.74	0.65	0.62	0.61	59.76	34.69	34.62	0.59	0.61	0.56	9	0.71	
Maximum value				65.67	38.21	39.39	0.70	0.68	0.69	64.14	39.46	44.23	0.66	0.65	0.65	14	0.82	

† *Chosen final classification tree, most accurate tree based on the table values*
b *Best among column values*
w *Worst among column values*

Figure 2. Final classification tree with TBDC decision (T=1 for active PTB and T=0 for non-PTB) as the target variable
[Note on job_category: 0=No work, 1=driver, 2=service worker/vendor, 3=student, 4=office employee/sales worker, 5=professional/self-employed, 6=laborer/unskilled, 7=overseas worker, 8=skilled worker/others]



The left portion of the classification tree demonstrates that in males, a diagnosis of active PTB involves interactions among the variables history of alcoholic beverage drinking, hemoptysis, job category, history of smoking, weight loss, and age. Conversely in females, there is individual association of the TBDC diagnosis of active PTB with hemoptysis, alcoholic beverage drinking history, and age (as seen on the right portion of the tree).

In Table 4, the final classification tree has an overall prediction accuracy of 64% for both training and data sets, with misclassification rates of 30.74 to 38.21%. Sensitivity and specificity range from 62% to 69%. The ROC scores (0.69 for the training and 0.66 for the test data) of the chosen tree (Tree 47) suggest we would be able to tell which one the TBDC will diagnose as active PTB in 69% of all cases for the training data, and 66% for the test data. The relative cost of 0.714, the lowest among the four candidate trees, denotes the overall accuracy of our chosen tree which has an error rate that is 71.4% of that experienced without a model.

3.4 Validation of loglinear and classification tree models

The total records gathered for 851 subjects are randomly divided into 600 (70%) and 251 (30%), respectively, as the training and test data sets. In the validation, there is consistency in the results for both training and test data sets since the final models apply as well to the test data, which was not used in building the model. In this study, the strength of the classification tree analysis is in the handling of continuous and multi-categorical variables by determining cutoffs and partitions anywhere throughout the tree. Its ability to operate even with missing values for some variables speaks well of maximizing the data, instead of removing entries from the analysis. Interpreting the magnitude and direction of association between variables through the odds ratios is the forthright advantage of loglinear analysis.

4. Conclusions and Recommendations

4.1 Conclusions

The decision patterns of the TBDC in diagnosing an active PTB case among sputum smear-negative PTB suspects are based on positive chest radiographic findings – which significantly associate with symptoms of hemoptysis and weight loss, history of alcoholic beverage drinking, and the demographic factor age (less than 40 years old).

Hemoptysis or coughing up blood is the most important variable in differentiating a TBDC decision of active PTB from non-PTB.

Sex is used as the root node variable in order to improve the classification accuracy of the model tree and explore differences in the sex-related factors, even if it is not individually associated with the TBDC decision.

While the classification tree expectedly demonstrates interactions among the six predictors in relation to a diagnosis of active PTB by the TBDC; the individual association of hemoptysis, alcoholic beverage drinking history, and age with the target variable is strikingly evident among females.

The loglinear model {AT}{HT}{TW}{TY}{WY} signifies that history of alcoholic beverage drinking (A), hemoptysis (H), weight loss (W), and age (Y) are individually associated with a TBDC diagnosis of active PTB (T); and there is an interaction between weight loss (W) and age (Y).

The complementary use of loglinear models and classification trees improves the conduct of association and classification analyses. The classification tree proves to be simple, interpretable, and is able to explicitly characterize and differentiate variable interactions between sexes in the attempt to describe the TBDC decision of diagnosing active PTB cases.

4.2 Recommendations

Presenting the most likely scenario of the TB Diagnostic Committee findings, the TBDC may find the proposed models useful as a decision tool in making a diagnosis of active pulmonary tuberculosis in support of the chest radiograph. The research outcome would contribute in minimizing subjectivity in chest x-ray readings and would make the most of the available simple findings for decision-making in the diagnostic approach to sputum smear-negative PTB patients.

The following additional recommendations are formulated for both statistical and public health aspects of the research. The author recommends to:

1. Use loglinear models and classification trees congruently in the construction of association and classification rules. Classification trees work effectively in the preliminary analysis for determining cutoffs and dichotomizing continuous and multilevel categorical variables prior to loglinear analysis.
2. Further explore categorical data using multiclass target variables in fitting classification trees. For instance, determine the association of demographic and clinical findings with the dependent variable having for target classes – a normal chest x-ray reading, minimal PTB lesions, and extensive PTB lesions on chest radiography.
3. Since the study is purely descriptive in modeling the TBDC diagnosis in terms of the associated demographic and medical characteristics; the interest then is to validate how well the TBDC findings measure up to sputum culture, the gold standard in the diagnosis of PTB. The author eagerly recommends observational and evaluation studies on the procedures and conduct of the TBDC deliberations.
4. The value of a good quality chest x-ray film to an accurate and prompt diagnosis of PTB is unquestionable. The author strongly proposes the formulation and implementation of strict measures to guarantee and monitor competent personnel

and well-equipped diagnostic centers to produce quality chest x-ray films of good visualization and with the recommended size of at least 11 by 14 inches. Efficient diagnosis leads to efficient TB control. Humanely and economically, patients with PTB will be spared from futile costs (caused by others' ineptitude) for undergoing repeated chest x-rays due to poor quality and inappropriately sized films.

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Knowledge, Attitudes, and Practices of Households in Relation to Avian Influenza

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Avian influenza, commonly known as bird flu, once threatened the lives of birds as well as of human beings. Caused by a virus, it is considered endemic in many parts of Indonesia and Vietnam and in some parts of Cambodia, China, and Thailand. Outbreak of many similar diseases can easily reach epidemic level because households have minimal knowledge of precautionary measures. This study conducted a survey on Filipino households' knowledge, attitudes, and practices related to avian influenza. Results of this assessment can help in the development of intervention strategies for the mitigation of the hazards the outbreaks may cause to humans. This is also beneficial to the country since it is concluded that there should be an improvement on the publics' knowledge of transmission and preventive measure, and that health professionals and other concerned agencies should provide effective information to prevent the disease.

Keywords: *knowledge, attitudes, practices, avian influenza*

1. Introduction

Every now and then, there are outbreaks of new diseases threatening the life of the entire human race. Some years ago, avian influenza became a public health concern among Filipino households. While it barely reached epidemic level, it still caused the public health officials to assess readiness among different stakeholders to deal with such problems.

Avian influenza—most commonly called bird flu—refers to an illness brought by any of the different strains of flu viruses, in particular, strains that has adapted to the human host. Bird flu viruses that are known to have adapted to human host belong to a species of virus called *Influenza A* virus. It has resulted to destruction of so many birds and even human deaths.

Most avian flu infection cases were identified in Southeast Asian countries like Vietnam and Indonesia. Though these countries are very near, the Philippines have remained bird flu free. The Philippine government, in cooperation with other private institutions, campaigned to keep the Philippines bird flu free. Several measures have been launched to protect the country's poultry industry and population from the influenza virus. The government formed the National Avian Influenza Task Force (NAITF) to stengthen bird flu protection program. All government agencies were mobilized to protect the Philippines from this deadly disease.

The Department of Agriculture (DA) provided the communities with practical information about bird flu. The Department of Health (DOH) also facilitated activities disseminating information on the current health threat. Symptoms on the disease and the necessary actions to be taken if a case of bird flu infection occurred were their primary topic of discussion. Upgrading 21 hospitals in preparation of a possible outbreak was also part of their program.

Public health authorities closely monitored outbreaks of human illness associated with avian flu especially in the nearby Asian countries. Airports and immigration officials implement a health check-up for the arrival of travelers to ensure that they are not carrying the disease. However, migratory birds also visit the country and can potentially spread the virus.

The Department of Environment and Natural Resources (DENR) and DA were tasked to draw up maps of specific areas in the country where migratory birds congregate and to publish a "do's and dont's" primer which lists down what one must do when in contact with birds. The Philippines has about twenty identified areas hosting migratory birds. These areas are major concerns of health officials since migratory birds are known to be likely carriers of the virus. In line with this, concerned authorities were asked to publish an inventory of avian flu symptoms and corresponding management procedures to take when infection is suspected. The government also requested the media to broadcast information on the bird flu.

In response to the rampant outbreaks of bird flu in different Asian countries near the Philippines, World Vision Development Foundation (WVDF) would like to do its share by implementing an intensive information campaign nationwide regarding the avian flu. The purpose of the education campaign is to prepare the communities in the prevention of this disease and to prepare them in the event of an outbreak of the avian flu in the country. Hence, to determine specific information needs to be disseminated, WVDF in coordination with the UP Statistical Center Research Foundation Inc. (UPSCRF Inc.) and the Civic Welfare Training Service class of the School of Statistics, conducted this study to understand households' perception on the avian flu.

The ultimate goal of the study is to prepare mitigation strategies intended for the households once avian flu happens by providing them practical information and useful knowledge regarding the disease and its prevention. Specifically, it aims to assess the knowledge, attitudes, and practices of adults and youths in both urban and rural households related to avian flu influenza. This study shall provide inputs for the information campaign which the WVDF intends to implement to enhance preparedness among various stakeholders.

2. The Epidemiology of Avian Influenza

Avian Influenza is a disease from viruses adapted to birds, but is sometimes mistakenly used to refer to other flu subsets (such as H5N1 flu) or the viruses that caused them (such as H5N1). All known avian flu viruses belong to the species called *Influenza A* virus. All subtypes (but not all strains of all subtypes) of Influenza A virus are adapted to birds, which is why avian flu is commonly interchanged with Influenza A virus.

According to the World Health Organization (WHO 2006), Avian flu virus transfers between poultry by contact of saliva, nasal secretions, blood and feces of an infected bird or with surfaces that are contaminated by these excretions, and body fluids from infected birds. Infection with avian influenza viruses in poultry causes two main forms of disease: the "low pathogenic" form may go undetected and usually causes only mild symptoms (such as ruffled feathers and a drop in egg production); and the "highly pathogenic" form which spreads more rapidly through flocks of poultry. This form may cause disease that affects multiple internal organs and has a mortality rate that can often reach 90 to 100 percent within 48 hours.

The highly pathogenic avian flu virus, H5N1—named after two proteins (hemagglutinin and neuraminidase)—is the newest virus responsible for this disease. It is easily transmissible between birds and poultry and is also highly lethal. H5N1 virus does not usually infect people, but infections with these viruses have occurred in humans. Most of these cases have resulted from people having direct or close contact with H5N1-infected poultry or H5N1-contaminated surfaces [Center for Infectious Disease Research and Policy (CIDRAP) 2006].

Low pathogenic H5N1 avian influenza virus, also known as "North American H5N1," is commonly found in wild birds. This form may go unnoticed and is not dangerous to birds and humans, although mutation of this form to a more lethal strain is a cause of apprehension. The highly pathogenic form of H5N1 however, is now considered the world's biggest current pandemic threat. This virus has raised concerns since it is especially virulent; it is spread by migratory birds; it can be transmitted from birds to mammals and in some limited circumstances to humans; and, continues to evolve (CIDRAP 2006).

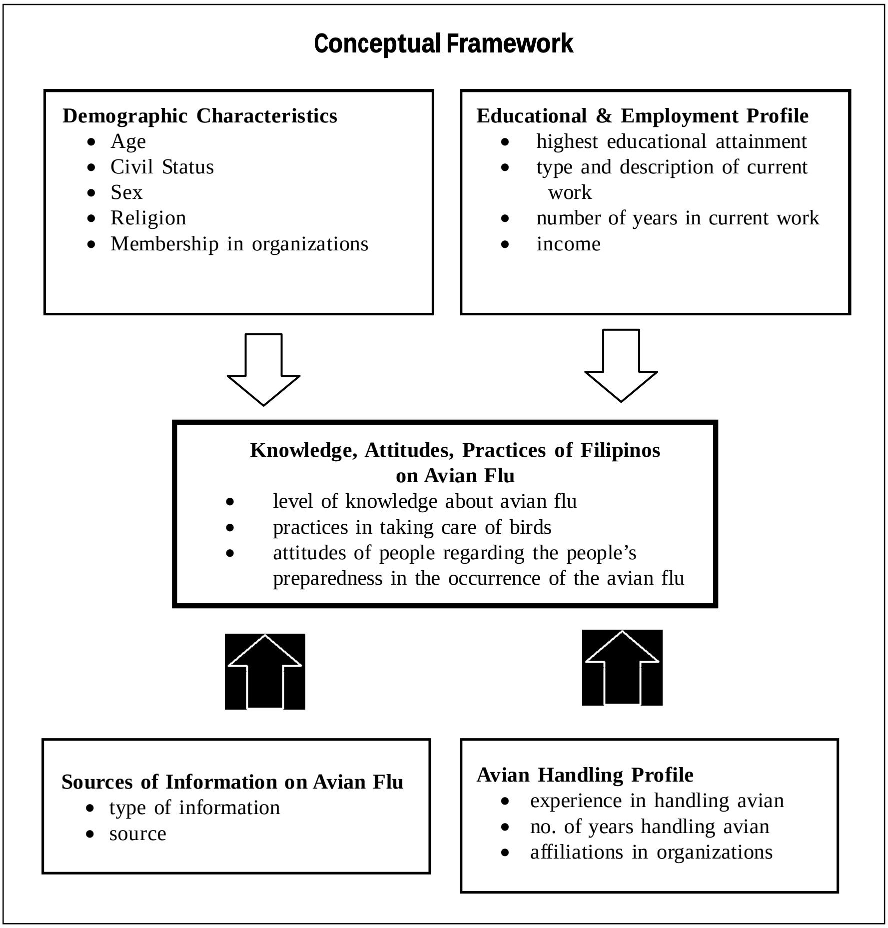
Flu infection in birds may show different symptoms that vary depending on the strain of virus that caused the infection. Symptoms range from mild common flu-like indications to highly fatal and contagious disease. Symptoms may include decrease in activity, drastic decline in egg production, facial swelling with swollen and bluish-violet colored combs and wattles, hemorrhages on internal membrane surfaces, virus isolation needed for definitive diagnosis, gasping for breath, muscle weakness/paralysis, diarrhea or sudden deaths that may reach 100 percent mortality [Center for Prevention of Disease and Control (CDC) and WHO 2006].

The US Food & Drug Administration has recently approved of Influenza A/H5 (Asian lineage) Virus Real-time RT-PCR Primer and Probe Set – a new and faster way of diagnosing strains of avian influenza in people suspected of carrying the virus (CDC 2006). Results of the test are available in four hours, much faster compared to past procedures that need two to three days. Rapid diagnosis of a person having a strain of bird flu is highly advantageous, given that H5N1 virus can cause death within 48 hours of infection.

Antiviral treatments for infected persons are available as Oseltamivir (commonly known and marketed as *Tamiflu*) and Zanamivir (*Relenza*) (CDC 2006). These treatments do not promise instant cure, but both can decrease the severity of the effects of the infection, if given to the patient within 48 hours after symptoms start to show. Tamiflu, the first H5N1 drug created, does not give immunity from viral infection but help decrease the effect of the symptoms and decrease the potential rate of transmission from person to person. One drawback from using this drug is its limited production due to low supply of its active ingredient – star anise. The recently discovered third drug alternative against H5N1 virus is *Peramivir*. Studies show that this new drug is more powerful than the two existing drugs in the market. Peramivir is considered as an emergency remedy for bird flu infections and a substitute drug if resistance from Tamiflu and Relenza develops. It is easier to administer and remains active longer since it is injected to the patients, while Tamiflu is taken orally and Relenza is taken through inhalation. It is also easier to mass produce since it is made of readily available synthetic raw materials. Peramivir is due to be licensed in 2008 or 2009 [Food and Drug Administration (FDA) and CDC 2006].

3. Methodology

The WVDF hopes to educate the people regarding the avian flu by having a comprehensive information campaign. As a benchmark, information on the



Conceptual Framework

knowledge and awareness of the stakeholders is very important. Furthermore, attitudes and practices of the respondents could augment the data. The figure below illustrates this framework which shall be the basis of the data to be collected and the analysis to be done in this survey.

To describe the characteristics of the individual respondents, there is consideration of the demographic, education, and employment components. Data collected for these components will help determine the level of knowledge of households about avian flu, the attitudes of people regarding avian flu, and practices in handling and taking care of birds. This will also determine the source and type of information they have regarding avian flu.

3.1 Sampling design

Data was collected in March 2007 in the municipality of Naic, Cavite. Naic is stratified into urban and rural barangays, two barangays, namely Barangay Ibayo (urban) and Barangay Labac (rural) were selected for the study. A simple random sample of 700 respondents (350 adults and 350 youths) were selected from each of the urban and rural areas. Youth are defined to be between 12 to 21 years old and currently studying while those 21 years and over are considered adults.

3.2 Method of data collection

The study collected data through a survey. To substantiate the quantitative profile of the respondents, a focused group discussion (FGD) was subsequently conducted. FGD is intended to help explain the dynamics of stakeholders' knowledge, attitudes, and behavior toward avian flu.

A survey instrument accounting for the different components of the framework was constructed. The questionnaire has four parts: the first part contains 13 questions concerning the demographic characteristics of the respondent; the second part consists of 17 questions on the engagement of respondents to fouls and poultry; the third part include 36 questions on bird flu awareness; and the fourth part have 13 statements to determine the attitude of people regarding bird flu. The questionnaire was phrased in the local language of the respondents (Tagalog). The average time of each interview is 30 minutes.

After conducting the personal interview, tables are constructed and indicators that need to be probed for the focus group discussion were identified. Four FGDs were conducted namely: adults in the urban community; youth in the urban community; adults in the rural community; and youth in the rural community. All of these FGDs were conducted in the Community Research Center of World Vision Development Foundation in Naic, Cavite.

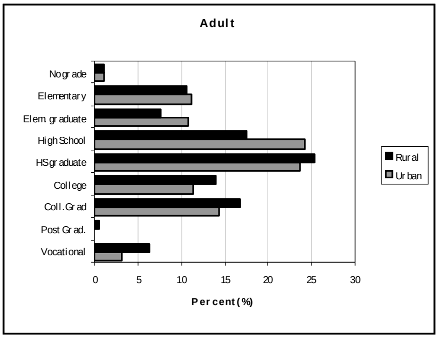
4. Results and Discussion

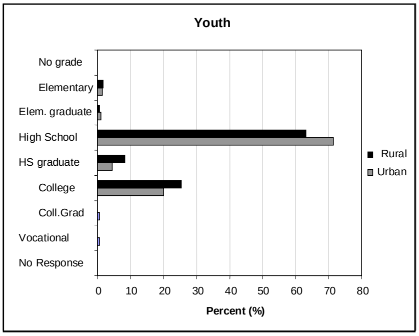
We discuss the findings from both the survey and the FGD. The profile of the respondents is first presented and then we identify the respondents' practices in taking care of chickens, ducks, and other birds, to assess the level of knowledge and awareness of the respondents concerning avian flu, and to determine their attitudes regarding avian flu.

4.1 Demographic and economic characteristics of respondents

We shall first look at the demographic profiles of the respondents. There are more female respondents both in urban and rural communities (66% and 61% respectively). Majority of the adults are married (67%) and almost all of the youths are single. Among the adults, many reached high school (21%) or have graduated from high school (25%). As shown in Figure 1, more adults are high school graduate, at college level, and college graduate in the rural community than in the urban. The youths more or less exhibit similar characteristics. Majority are still in their high school years and more have graduated from high school or have reached college in the rural community than in the urban.

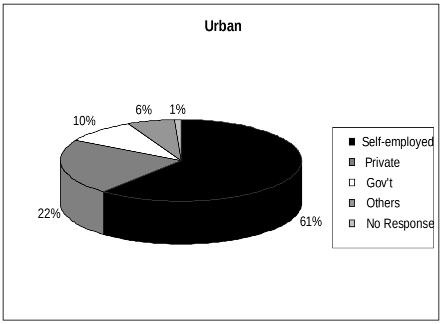
Figure 1. Frequency Distribution of Highest Educational Attainment by Type of Barangay





Since college graduates among adults are atypical, unemployment would be usual. Majority of the rural adults are unemployed (55%), more in the urban area (59%). Among those employed, Figure 2 shows that majority are self-employed in both urban and rural communities. In addition, majority of those who are working only earn less than P10,000 a month. Figure 3 shows the income distribution of these adults in the urban and rural areas.

Figure 2. Frequency Distribution of Employment Type by Type of Barangay among Adults



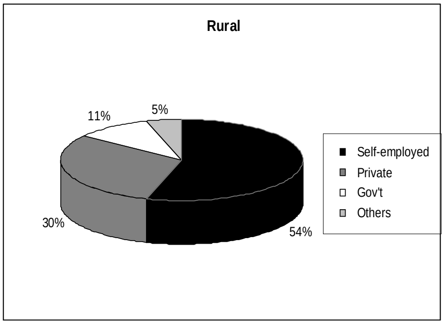
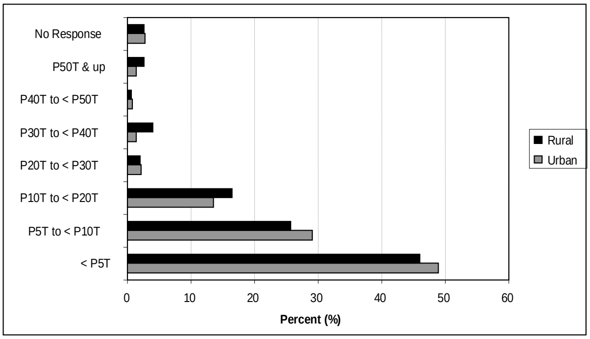
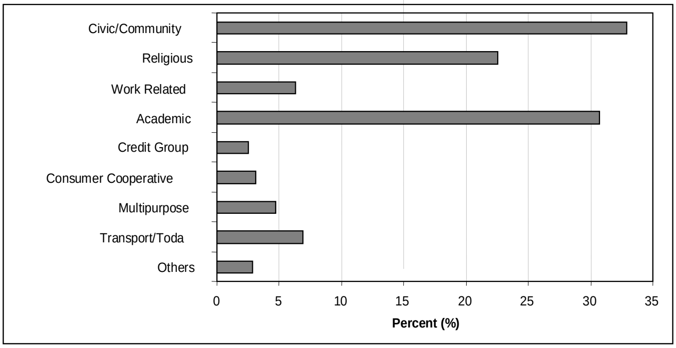


Figure 3. Frequency Distribution of Income by Type of Barangay among Adults



Organizations are particularly helpful to their members not only by providing assistance with respect to their declared mission and function, but also in disseminating news and information to its sphere of influence. Thus, with the avian flu information campaign in mind, knowing whether the respondents belong to a particular organization or organizations would be relevant. Most of the respondents are not affiliated with any organization (74% adults, 80% youths). On the other hand, Figure 4 shows that there are more organization memberships among adults than youths, both in the urban and the rural communities; and in addition, mostly are civic, academic, and religious in nature.

Figure 4. Percentage Membership among Different Organization Types



4.2 Characteristics of FGD respondents

The adult-urban respondents consist of six females and one male with ages 47 to 50 years old. Five are married, one is single, and the other one is a widow. All are Catholics of which six are high school graduates and one is a college graduate. Only five adults are employed but all are members of an organization. However, for the adult-rural respondents, there are six females with ages 42 to 56 years old. Half are married and the other half are widows. There are four Catholics, one Christian, and one Baptist. Two of them are college graduates and the rest are high school and elementary graduates. Of the six, five are currently employed and all are members of organizations.

The youth-urban respondents are four females with ages 15 to 21 years old. All are single, three are Catholic and one is a Born Again Christian. Only one graduated from college and the rest are high school graduates. Lastly, the youth-rural respondents consist of three girls and two boys with ages 12 to 17 years old. All are single, high school students, and are members of an organization. Three of them are Catholic while the other two are Born Again Christians.

4.3 Practices in handling fowls and poultry

Respondents were asked in what ways (if there is any) they have had contact with poultry or fowls in the past six months. Their responses are summarized by type of barangay and by age classification in Figure 5. It is evident that eating chicken is the top answer, followed by preparing fowls for food. Raising poultry comes next in the rural area and among adults, which is then followed by raising pet birds. However in the urban area and among youths, raising pet birds comes on top of raising poultry. We shall focus on the practices of respondents regarding these top four answers.

Figure 5. Percentages on Ways of Contact with Fowls by Type of Barangay and by Age Class

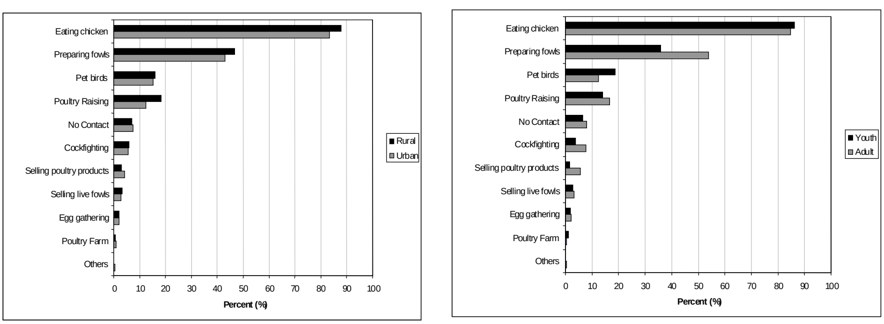
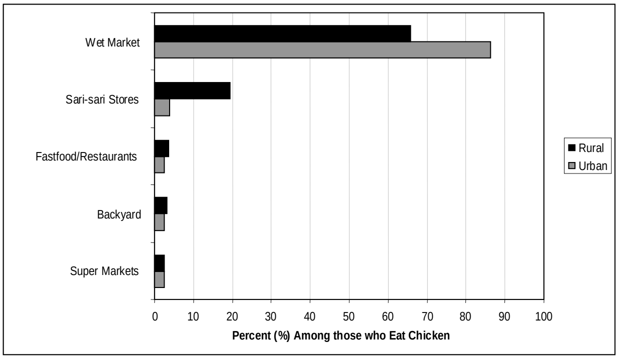


Figure 6 summarizes the top five responses to the question on where they usually get the chicken they eat. There is no doubt that majority buy chicken for food from wet markets over supermarkets, primarily because of the price and availability. The FGD supports this preference of wet markets to supermarkets for the same reason.

Figure 6. Top 5 Sources of Chickens Ate



One notable difference between the respondents in the urban and the rural area is that in the latter, there is quite a number who opt for sari-sari stores. Perhaps, a number of sari-sari stores in rural areas offer the convenience of selling chicken while in urban areas, chickens are primarily available only in markets. The FGD affirms the survey with respect to respondents buying chicken at sari-sari stores due to its ease and proximity.

Washing of hands has been widely accepted to be an effective way of preventing the spread of many diseases. Hence, the respondents were also asked how frequently they wash their hands. Mainly because of the hygienic culture of Filipinos, it is as expected in Figure 7 that majority of the respondents, both in rural and urban areas, always or often wash their hands when eating. There is however a very insignificant percentage reported not washing hands before eating.

For the second top answer, preparing fowls for food and sources of fowls prepared for food are presented in Figure 8, while the frequency of hand washing when preparing fowls for food is in Figure 9. Majority of those who prepare fowls for food get them from wet markets, and there is also a number in the rural area who opt for sari-sari stores as source. There is a higher percentage of respondents who wash their hands always in preparing food.

Another sanitary precaution to avoid certain diseases including bird flu is the use of gloves when handling poultry and other birds. The respondents were also asked whether they use gloves when preparing food. It is not surprising to note in Figure 10 that only a few do so. There are two possible reasons: first, Filipinos are not accustomed to wearing gloves when preparing food; and second, there is not a single case of bird flu yet in the Philippines. So Filipinos are still lenient in observing this precautionary measure. The FGD affirms that wearing gloves is not a usual practice when preparing food. One reason stated by a youth-rural respondent is that she finds the chicken clean.

Figure 7. Frequency of Washing Hands when Eating Chicken

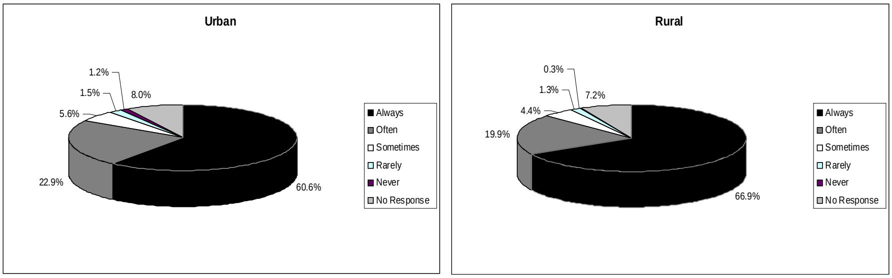


Figure 8. Top 5 Sources of Fowls Prepared for Food

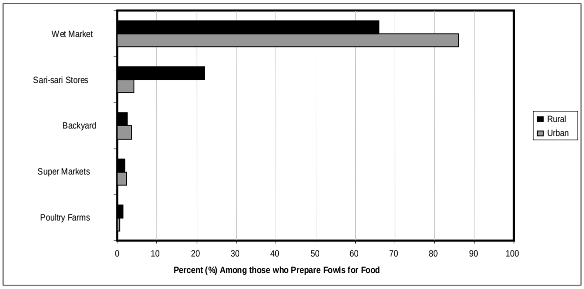


Figure 9. Frequency of Washing Hands when Preparing Fowls for Food

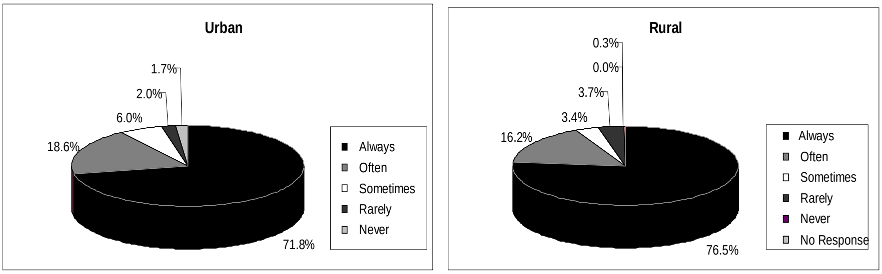
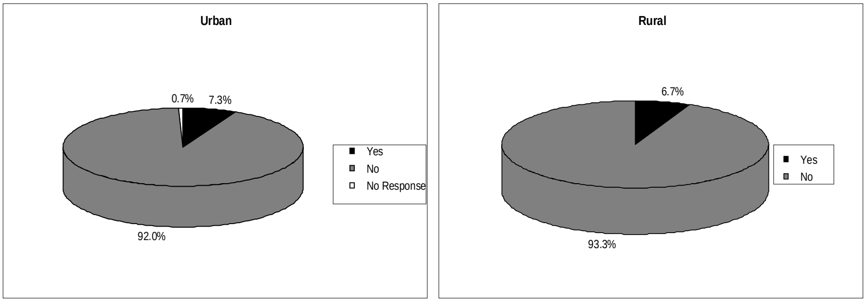


Figure 10. Frequency of Using Gloves when Preparing Fowls for Food



Meanwhile, among those who raise poultry in the urban area, top sources, in general, are wet markets, followed by backyard, and then relatives or friends (see Figure 11) . In the rural area, however, the top answer is friends and relatives, followed by backyard, and then wet market, with differences between percentage responses being quite small, though. When probed what they meant by "backyard," majority said that they mean the offspring of their poultries – which they have had a long time ago, while some would reply that the poultries they raise went astray into their backyard. We can still observe the same practice of frequent hand washing among those who raise poultry in Figure 12, and reluctance in using gloves when handling poultries in Figure 13.

Figure 11. Top 5 Sources of Poultries Raised

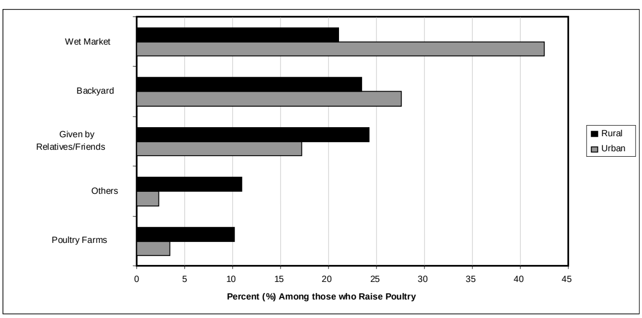


Figure 12. Frequency of Washing Hands when Handling Poultries Raised

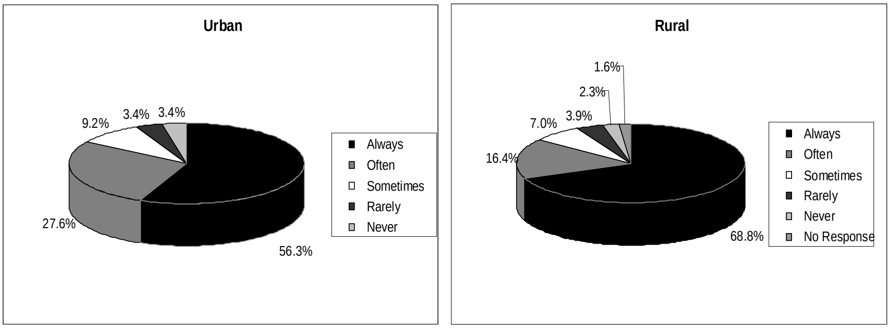
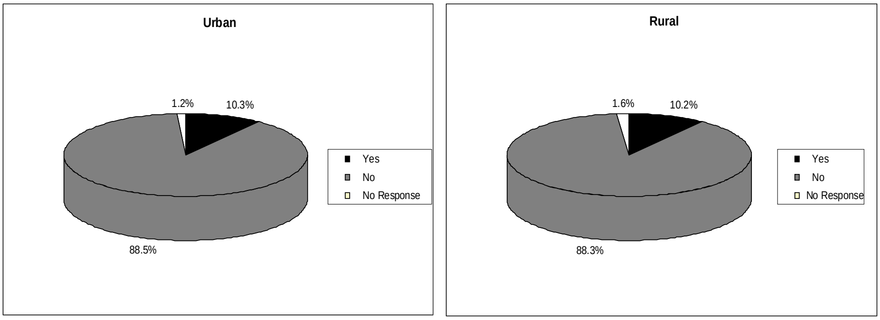


Figure 13. Frequency of Using Gloves when Handling Poultries Raised



Finally, for those who have pet birds, the urban and rural respondents somewhat have different responses on where they usually get or buy their pets (see Figure 14). Urban samples source primarily from wet markets, then from their backyard, or from pet shops. On the other hand, rural samples acquire their pet birds predominantly from relatives or friends, then from backyard, and wet market ranks third. They are normally expected to source out their pets from pet shops but that is not true in this case. Pet shops ranked fourth only in the rural community because of the lack of profusion or demand for pet shops in this area. As implied in Figure 14, many rural respondents acquire their pets from friends and relatives. As one might observe in the Philippines, pet shops are usually located in urban areas. Pet shops also impose higher prices.

Frequent hand washing is also prevalent among those who have pet birds, but they are disinclined to use gloves in handling their pet (see Figures 15 and 16). These are as well, consistent observations as with the practices of those who have contact with fowls in some other ways.

Figure 14. Top 5 Sources of Pet Birds

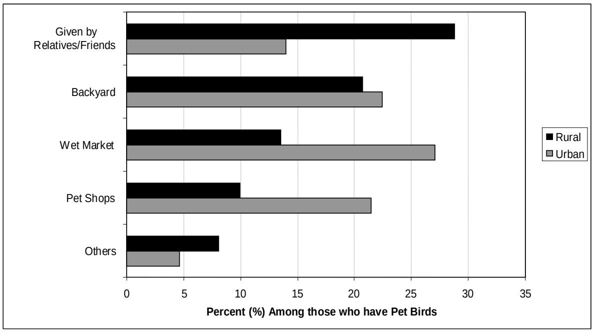


Figure 15. Frequency of Washing Hands when Handling Pet Birds

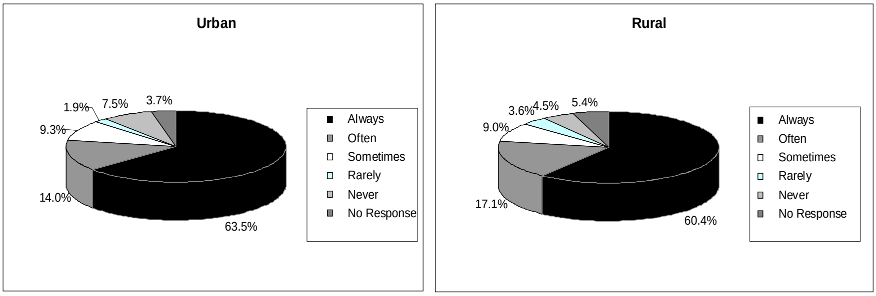
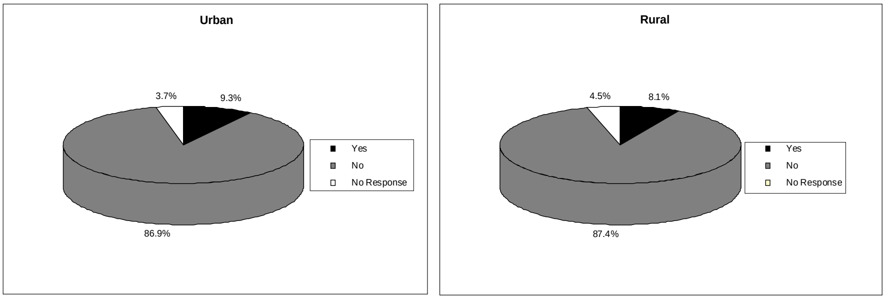


Figure 16. Frequency of Using Gloves when Handling Pet Birds



Aside from chicken, Filipinos are also consumers of poultry products and their derivatives. The most common, among all these, are eggs. If fresh from the poultry house, eggs are probably still stained with chicken feces or urine. Thus, in case of a bird flu outbreak, eggs can be a source of infection. The respondents were asked whether they wash the eggs before consuming or using them. In Table 1, most of the respondents practice washing eggs before consuming them. The proportion who washes eggs before using in the rural community is around 10 percent higher than that in urban communities. Adults behave similasrly as the youths. From the FGDs, they usually wash the eggs with water if there are feces, dirt, stains, and feathers on its shell. However, some noted that if they find the shell clean, they do not wash it anymore especially if the egg is to be fried since egg shells will be removed anyway. On the other hand, if the egg is to be boiled, they have to wash it first since egg shell is included in the boiling process.

Table 1. Frequency Table for Washing Eggs by Type of Barangay and by Age Class

	Type of Barangay				**Age Class**				**ALL**	
	Urban		Rural		Adult		Youth			
	Count	%	Count	%	Count	%	Count	%	Count	%
Yes	381	59	444	68	401	62	424	65	825	64
No	253	39	195	30	235	36	213	33	448	34
No Response	14	2	12	2	9	1	17	3	26	2

Those raising fowls are the most vulnerable carriers in the event of an outbreak. The respondents were asked what type of fowls or birds they raise. The top 3 answers, shown in Figure 17, are chickens, doves, and pet birds (e.g., love birds, mynah, and parrots). Other answers include quail, turkey, and goose, reported by very few respondents. Chicken naturally ranked number one since this is perhaps, among the birds, the most common food for man. A higher percentage in the rural area raises chicken than in the urban. It can also be seen in the graph that more adults raise this bird than youths. Doves however, are more common in the urban area than in the rural. Since raising doves is more of a leisure than business, one can notice that youths are more inclined in raising them than adults. This is also true for pet birds. Rural people, meanwhile, are also more predisposed to pet birds than urban people.

Table 2 shows the duration the respondents have been taking care of these birds. More than half of those who are taking care of chickens have been doing so for more than a year. Of those who have doves, many have been engaged for more than a year also. This too goes for those who have pet birds. Barely a few started raising these fowls just recently.

Figure 17. Top 3 Fowls Raised

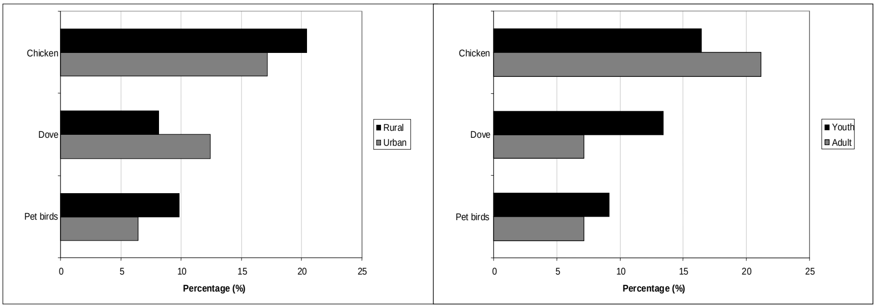


Table 2. Since When the Fowls were Raised

	Chicken		Dove		Pet Birds	
	Count	%	Count	%	Count	%
Less than a week	6	2	5	3	3	3
A week	5	2	8	6	5	4
Almost a month	11	4	11	7	5	4
A month	18	7	21	15	10	9
Almost a year	53	20	34	24	28	25
A year	20	8	14	10	14	2
More than a year	141	54	45	31	45	39
Others	9	3	5	3	-	0
No Response	-	0	1	0.7	4	4

Consider now the practices of the respondents in taking care of these three birds. Sound feeding practices are very important for those who have been taking care of or domesticating not only birds, but other animals as well. The health of their pets mostly depends on the quality of food that they give. The respondents were asked how frequent they give their pet birds the prescribed feeds. Most of the respondents who raise chicken, doves, and pet birds are providing prescribed feeds for their fowls daily. More respondents in the rural area (90%) practice the daily supply of feeds for chicken than in the urban area (83%). Adults (91%) also are more inclined to do this than youths (82%). Meanwhile for those who raise doves, the proportion of respondents who give daily prescribed feeds in the urban and rural area are practically equal. However, adults (90%) tend to practice this more than the youths (74%). The same pattern as those who raise doves is exhibited by those who have pet birds. The proportion of respondents who give daily prescribed feeds in the urban and rural area are almost the same, but a higher percentage of adults (82%) give daily prescribed feeds to their pet birds than youths (59%).

The respondents were also asked how frequent they provide the birds they raise with vitamins or food supplements like booster or grower. Their responses are quite different from the previous question. Many respondents (37%) give food supplements to chickens daily and to those who have pet birds, with 22 percent of the respondents practicing this. It is quite the opposite though, for those who raise doves, where more than half (51%) prefer not to give any vitamin or food supplement to their pet. Generally, rural people are more inclined to give vitamins and food supplements daily than urban people, and adults prefer also to practice this more than youths.

Feeding though, is not the only factor affecting the health of the fowls that people raise. Proper cages or housing structure for raising them in a sanitary way is also a must. Those who raise fowls therefore were asked where they keep their pets. For each of the three fowls, the top answer is “in the backyard,” followed by “in a separate coop.”

Interestingly, there are a few who keep chickens inside the house. Nonetheless, a higher percentage of those in urban (84%) keep their chickens in the backyard compared to those in the rural area (75%). A higher proportion of rural respondents (21%), however, keep their chicken in separate coops than urban respondents (9%). Also, a higher proportion of youths (84%) prefer to raise their chickens in the backyard compared to adults (75%), while a higher proportion of adults (18%) prefer to raise their chickens in separate coops compared to youths. These behaviors are also exhibited among those who raise doves, and among those who raise pet birds, except that in the latter, a higher percentage opt to keep their pet birds in the backyard instead in the rural area (70%) than in the urban area (58%).

When asked how frequent they clean the bird cages or houses of the fowls they raise, 52 percent of urban residents replied daily cleaning of cages while 48 percent for rural residents. Surprisingly, there are those who said that they never clean the cages/houses of the fowls they raise. There is a higher percentage of respondents who clean the birdcages or houses in the rural community compared to the urban community among those who raise dove and pet birds, but it is the other way around among those who raise chicken. Moreover, adults are more prompted to clean the cages daily than youths, as indicated by the consistently higher percentages, in each of the three kinds of fowls.

Another important factor in controlling the contagion effect of bird flu is the practices in handling dead fowls since the inflicted can easily die. Most of the respondents (61%), in general, have not experienced having their fowls dying. However, there are similar proportions of respondents who experienced death of their chickens, doves and pet birds. Meanwhile, there are higher percentage of respondents who have had fowls dying due to a disease in the rural area (40%) than in the urban (35%), and among the youths (43%) as compared to adults (31%). This is a result of the differences between the feeding and sanitation practices of adults and youths that was noted.

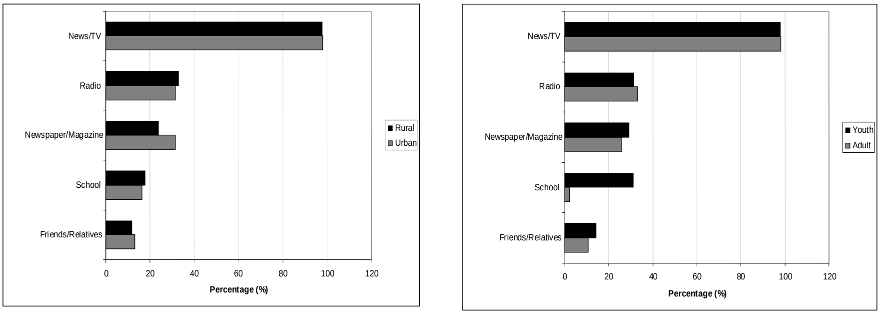
Respondents who have had some dead fowls due to the disease were then asked how they dealt with the dead bird. Majority buried the bodies of the dead fowls whether it is a chicken, a dove or a pet bird. The rest either threw them away or burned them. There are those who still perceive a dead chicken (6%) or a dead dove (2%) edible. Higher proportion of respondents are accustomed to burying in the urban area (77%) compared to the rural area (70%) for chickens and pet birds, but a lower percentage for doves. On the other hand, it seems that youths (80%) are inclined to burying dead fowls more than adults (69%).

4.4 Avian flu knowledge and awareness

The respondents were asked whether or not they, at the very least, heard about avian flu or bird flu. Greater majority responded positively. There is little difference in the percentage of those who have heard about bird flu between urban (90%) and rural (89%), but it seems that more youths (92%) have heard it compared with adults (87%).

Those who have heard about bird flu were then asked where they have heard about it. The top 5 responses were (as shown in Figure 18) news/TV, radio, newspapers/magazines, school, and relatives/friends. The FGD supports television as the primary source of information. They learned about the disease from news programs like *TV Patrol* and *24 Oras* of ABS-CBN and GMA networks, respectively.

Figure 18. Sources of Information about Avian Flu



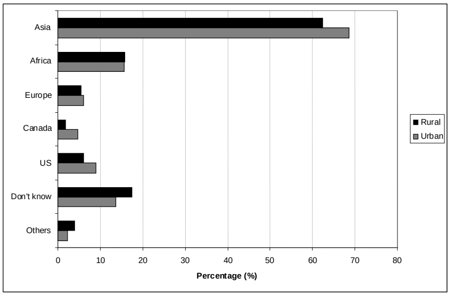
The urban and rural areas do not exhibit much difference with respect to their sources of information, though it seems that slightly more respondents sourced from newspapers or magazines in the urban area than in the rural. From the FGD, both urban and rural adults get additional information about avian flu from newspapers like *Tumbok* and *Philippine Star*. However, other respondents got their information from seminars given by DOH and WVDF. Youths and adults do not show large differences on the source of information.

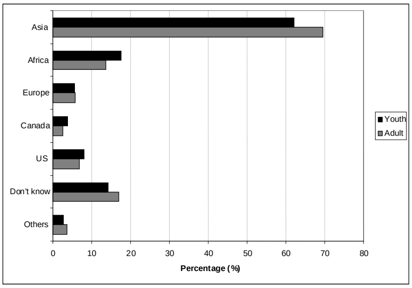
The respondents were also requested to assess how much they know about bird flu. Majority (77%) reported that they are somewhat aware about the issue. Barely 4% believe that they are very familiar with bird flu, and there are still those who are not aware (19%). The level of awareness in the rural area and urban area do not differ much. More adults believe that they are very aware of the issue compared to youths, but ironically, a few more adults also are not aware of bird flu in contrast to the youths.

Regarding the length of time the respondents have been aware of bird flu, more than half of the respondents (52%) responded to be aware for more than a year already. This is consistent on the fact that bird flu has been reported in other parts of the world more than a year ago. Other respondents became aware of it for a year (28%), a month (17%), and a week (3%).

In trying to identify what particular aspects about bird flu the respondents do know, certain questions were asked and they were requested to answer them to the best of their knowledge. They were asked to identify what areas have been or is affected by bird flu. In Figure 19, a lot of them believe that bird flu has already infected Asia. There is a higher percentage of respondents in th rural area, however, do not have any idea on places already infected. A slightly higher percentage also of adults does not know what to answer in comparison to youths.

Figure 19. Areas Affected by Bird Flu according to the Respondents





When asked to identify the original carrier of bird flu virus, more than half (58%) answered wild birds, some believe that poultries (16%) are the carriers, a few think it is humans (7%) and mammals (8%), and a few do not have any idea. The respondents were then asked if they are aware of any migratory birds from other countries that visit our country, and if they know any law about birds. Majority of the respondents (67%) are not aware of any migratory bird that come to the Philippines and more than half (55%) are not aware of any law regarding fowls. The

FGD supports the results of the survey on the lack of knowledge of respondents about migratory birds and laws regarding fowls.

The respondents were asked how they think fowls get infected with bird flu. The top answer is “contacts with live fowls infected with bird flu” (49%), followed by “touching the feces/urine of infected fowls” (40%), and “contacting dead fowls infected with bird flu” ranks third (34%). Many also believe that contacts with dead fowls even without bird flu can still be a cause of infection (21%). Only the top answer in the survey is consistent to that cited by adult respondents in the FGD. Other reasons cited by the adults on how fowls get infected with bird flu are chemicals mixed in food, inventions to make the chickens healthy for export, polluted air, hot temperature, dirty food, water, environment, and weather. The youth respondents, on the other hand, say that birds get infected with avian flu due to food eaten, pollution, dirt they get from surroundings, dirty coops, no vitamin supplements, and improper taking care of birds.

More than half of the respondents believe that bird flu cannot be detected in birds. Perceptions between urban and rural communities are basically the same for this question, as well as between adults and youths. Those respondents who said that bird flu can be detected in birds were asked what symptoms are present when a bird is infected with bird flu. The most frequent response is “moves with difficulty” (47%), followed by “refuses to eat” (46%), then by “secretes nasal mucus” (45%). A handful have no idea. In the FGD, the respondents also reported the same symptoms present in birds infected with bird flu with the addition of “rashes,” and “feathers falling-off.”

The respondents were asked whether they believe if bird flu can infect humans. Majority of the respondents (83%) think that humans can possibly acquire the bird flu disease. When asked about their opinion on how humans can be infected with bird flu, more than 70 percent replied “eating infected poultry products” and 49 percent answered “contact with fowls infected with bird flu.” Some believe that “contact with other people infected with the disease” and “contact with dead fowls infected with bird flu” are possibilities. The FGD is consistent with the results of the survey.

The respondents were asked about how they perceive bird flu as a threat to themselves, their family, and the country as a whole. Most of the respondents (70%) believe that it is indeed a big threat. Certain hierarchy was observed with the highest percentage exhibited when they were asked with respect to the country, and then on second rank, with respect to their family, and with respect to self is last. This structure can also be observed in the urban and rural subgroups, as well as the adult and youth subgroups.

The respondents were also asked how they think humans can be protected from bird flu infection. The most frequent answer is "washing hands after contacting fowls" (44%). This is reflective of the practices in handling fowls discussed in the previous section, where most respondents are accustomed to frequent hand washing, see Table 3 for details.

The respondents were then asked if they have heard or read any antiviral drug to treat a person with regular flu and a drug to treat someone with bird flu. Though majority of the respondents (68%) are aware, it is rather surprising that 32 percent are still uninformed about any drug used to treat regular flu. This is more evident among youths (35%) than adults (28%). On the other hand, nearly 90 percent said that they have not heard any drug to treat bird flu yet, which is consistent even after zooming in to the different subgroups.

Table 3. How Humans can be Protected from Bird Flu according to the Respondents

	Type of Barangay				Age Class				ALL	
	Urban		Rural		Adult		Youth			
	Count	%	Count	%	Count	%	Count	%	Count	%
Washing hands after contacting fowls	217	42	228	46	219	47	226	41	445	44
Avoid fowls	148	29	143	29	151	33	140	26	291	29
Not using/consuming poultry products	150	29	137	27	141	30	146	27	287	28
Cooking poultry products well	134	26	147	29	138	30	143	26	281	28
Avoid dead fowls	127	25	130	26	109	23	148	27	257	25
Quarantine infected fowls/persons	104	20	132	26	124	27	112	21	236	23
Being aware and knowledgeable	0	0	5	1	3	0.6	2	0.4	5	0.5
Others	12	2	16	3	18	4	10	2	28	3
Don't Know	7	1	6	1	7	2	6	1	13	1

In lieu of launching an intensive information campaign, which is the fundamental reason why this survey was conducted, the respondents were asked to identify what particular aspects about avian flu they want to know more. In Table 4, we see that majority desire to be oriented on how to be protected from avian flu, to discern the symptoms of bird flu, or how will they be able to discern whether a person or fowl already has bird flu, and what to do in case they manifest symptoms of bird flu. Less than 50 percent want to know how human could be infected with bird flu, consequences of bird flu, areas that have/had cases of bird flu, and on whether there are any cases of bird flu in the Philippines. There were few, however, who said that they do not need any additional information regarding bird flu.

There are few more items in the questionnaire that still deals with the knowledge of the respondents regarding avian flu, where they were asked to state their level of agreement or disagreement about a particular statement. The respondents are slightly inclined to agree that gloves can serve as protection from bird flu when handling fowls. Meanwhile, they are predisposed to disagree that eating poultry products is still safe even during a bird flu outbreak, as well as to that of infected fowls being safe to eat by cleaning and cooking them thoroughly. Majority agree that a bird flu outbreak can really disrupt and affect social and business activities. More than half also believe that the government has the capability to control and eradicate the disease in case of an outbreak in the Philippines.

Table 4. Information Desired

	Type of Barangay				Age Class				ALL	
	Urban		Rural		Adult		Youth			
	Count	%	Count	%	Count	%	Count	%	Count	%
How to get protected from bird flu	345	68	332	67	303	65	374	68	677	67
What are the symptoms of bird flu	299	59	304	61	279	60	324	59	603	60
What to do in case you happen to have symptoms of bird flu	260	51	260	52	255	55	265	49	520	51
How can human get infected with bird flu	233	46	259	52	229	49	263	48	492	49
What are the consequences of bird flu	206	40	210	42	176	38	240	44	416	41
Areas that have/had cases of bird flu	184	36	193	39	176	38	201	37	377	37
Are there any cases of bird flu in the Philippines	155	30	146	29	133	29	168	31	301	30
Do not need additional information	16	3	21	4	24	5	13	2	37	4

4.5 Avian flu attitude

The previous section has summarize the knowledge reported by the respondents pertaining to avian flu. This could serve as input in designing an efficient information campaign about the disease. It is not enough though, to present facts about avian flu to people. In case of a bird flu outbreak, their attitudes will also be vital in the success of controlling the disease. This section is devoted to elicit information about the attitude of the respondents regarding avian flu. They were also asked to state the extent of their agreement or disagreement to certain statements.

The respondents are really concerned about the threat that bird flu poses for them and their family. Majority of the respondents would feel concerned when they have symptoms such as fever, cough, sore throat, colds, body aches, and headaches, even if there are still no reports of bird flu cases. In relation to this, they want to make sure that if a family member exhibits some of the symptoms of bird flu, this will be treated immediately by medical specialists. In fact, nearly all respondents stood on the agreement side. Moreover, majority of the respondents either strongly agree or agree that vaccine should be developed that should serve as protection against bird flu. The FGD also exhibits the same sentiments as that of the survey result that sick family members should consult a medical specialist to make sure that they will be properly taken cared of, and giving importance to the development of a vaccine to help prevent and control the disease.

In the event of a bird flu outbreak in the Philippines, the proportion of those who agree that they are prepared are as much as those who are not prepared. There are however, quite a few more youths that do believe they are prepared than those who do not. On the other hand, there are lesser adults who do believe that they are prepared than those who do not. The FGD respondents are also divided as to whether they are prepared and not prepared in case of a bird flue outbreak. They are more concerned in becoming prepared by knowing the symptoms of bird flu, precautionary measures, and possible solutions.

With regard to the capability of the government to control a bird flu outbreak in the country, more respondents agree that our government can do so, though, about a fourth is unsure or neutral. The FGD supports the survey results for the adult-urban respondents. They believe that the government has the responsibility to respond to such problems and that they have confidence in the past performance of health authorities. However, the adult-rural, youth-urban, and youth-rural respondents have opposite sentiments to those of the adult-urban respondents. They believe that the government has no capacity to control or stop an outbreak of avian flu if that happens in the country. The reasons given are no/little health funds, corrupt government officials, no information dissemination, no medicines, does not prioritize important issues and concerns, not enough modern technology, and no scientific know-how.

In case of a bird flu outbreak, majority agree to hoard food, medicines, and other supplies. In the FGD, the respondents also agree to hoard food, medicines, and other supplies but the adult-urban respondents expressed concern about hoarding medicines since they believe that medicines are meant to be shared to others. In addition, they expressed disagreement to panic-buying to avoid chaos.

When there have been reports of bird flu cases in the Philippines, on the other hand, majority disagree to continue eating poultry products. This is confirmed in the FGD since the respondents' are fearful of being infected. They will only again eat poultry products if there is already an advisory from the government that poultry is safe to consume. However, one youth-rural participant says that he will still continue to eat poultry products since they get their chickens only from their place.

More than half agree, more than a fourth still stands to disagree, and 14% could not decide to kill all their pet fowls or chickens if some of the chickens or birds they raise were found to have bird flu. Moreover, a larger proportion tends to disagree among youths than among adults. This is validated in the FGD wherein the adult respondents agree to kill all their pet fowls or chickens if needed in case some are found to have bird flu. The reason they gave is to prevent further widespread infection. However, if the pet fowls or chickens are their source of income, they suggest doing the following: just kill only those who are infected and sell the healthy ones or have a veterinary doctor check the health condition of the birds. For the youth respondents, they disagree to kill all the birds since they pity them and treat them as pets. They would rather separate the infected ones from the non-infected and let the infected ones either die naturally or kill and burn them if suspected with bird flu.

Majority of the respondents are willing to adhere to the advice of health officials in containing the disease if they would have the bird flu and required to stay at home or away from other people for two to three weeks. Moreover, most of the respondents are cautious not to travel to infected areas. In the FGD, some respondents do not share the same sentiment in the willingness to follow the advice of health officials, if those infected are family members. However, they will comply if necessary. Pertaining to avoiding traveling to places in the world with cases of bird flu, the FGD is consistent with the survey results.

Finally, 80 percent of the respondents indicated willingness to attend seminars regarding avian flu.

5. Summary, Conclusions, and Recommendations

The most common way of respondents having contact with birds is through the preparation and consumption of fowls for food. Generally, but most especially among those in the urban area, they purchase or obtain these fowls from wet markets. There are quite a number of rural respondents, however, who consider sari-sari stores as an alternative. In line with the hygienic nature of Filipinos, most respondents have been practicing frequent hand washing when in contact with birds. They, however, are not accustomed to wearing gloves while handling fowls.

Many respondents are also engaged in raising poultries and pet birds. In the urban area, these fowls are more commonly acquired from wet markets, while in the rural area, the most common mode of acquisition is through the generous bestowment of their friends or relatives. It was also observed that chickens, doves, and pet birds are the most common types of birds raised by the respondents. Many of them keep these fowls within the perimeter of their backyard or in separate coops, but interestingly, there are those who raise their chickens inside the house. In addition, though majority practice cleaning the bird houses or cages daily to weekly, some reported that they never clean the houses of the fowls they raise. Meanwhile, the respondents are highly conscious in giving them prescribed feeds but are less inclined to provide vitamins. The data also showed that some have experienced having their fowls die due to a disease. More often than not, they bury the corpses but there are a few who still consume them for food. These are the practices of the respondents.

Almost all of the respondents have already heard about the disease but only a small percentage thinks that they know the issue very well. Since they think that avian flu is a big threat not only to themselves but to their family and to the country as well, many expressed the desire to know how to be protected, discern the symptoms, and what to do in case a person happen to have these symptoms.

Attitudes about avian flu were also elicited from the respondents. It was found out that they are very concerned about an outbreak of the disease here in the country. Though many believe the capacity of the government to contain and control the disease, the proportion of those who think that they are prepared for an outbreak and that of those who think otherwise are nearly equal. Nonetheless, it is well enough that majority are willing to heed the advice and policies that shall be imposed by health officials in controlling the spread of the disease. Moreover, should seminars and information campaigns be conducted, almost all of them are willing to participate. The common sources of information are television, radio, and newspaper. Likewise, many youths have obtained information from school.

Hence, based on the knowledge, attitudes, and practices of respondents in relation to avian influenza, there should be proper, efficient, and consistent dissemination of information about bird flu. We now give a list of recommendations on the kind of information campaign about avian influenza to prevent the outbreak in the Philippines:

1. People who have frequent contact with birds should be targeted primarily. Enhancement of knowledge and change in behavior should be of utmost concern.
2. Community leaders especially in the barangay level should be knowledgeable about the avian flu disease and disseminate information thru forums or seminars to their constituents.
3. Proper information materials regarding avian flu should be developed for the different target groups like children (thru cartoon and games), teenagers (comics and stories), farmers (posters), professionals (posters and brochures), and others (billboards).

4. Television networks, newspapers, radios, schools, organizations are good venues to educate the people and diffuse information.
5. It will also be beneficial if a website devoted to avian flu be provided since many are acquiring and accessing information thru the internet.
6. To increase the effectivity of these efforts, there should be constancy in providing information. More emphasis should be given on topics covering ways to get protected from the disease, symptoms of bird flu and actions to be done in case of manifestations of these symptoms, and means of infection.
7. Experts on avian flu should be involved in these campaigns to increase credibility.

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Backfitting Estimation of a Response Surface Model

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The backfitting algorithm is used in estimating a response surface model with covariates from a data generated through a central composite design. Backfitting takes advantage of the orthogonality generated by the central composite design on the design matrix. The simulation study shows that backfitting yield estimates and predictive ability of the model comparable to that from ordinary least squares when the response surface bias is minimal. Ordinary least squares estimates generally fails when the response surface bias is large, while backfitting exhibits robustness and still produces reasonable estimates and predictive ability of the fitted model. Orthogonality facilitates the viability of assumptions in an additive model where backfitting is an optimal estimation algorithm.

Keywords: *backfitting, response surface model, second order model, central composite design*

1. Introduction

Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes (Myers and Montgomery 2002). Response surface designs are powerful class of experimental designs, possibly identifying a closer link between empirical and theoretical response surfaces than the traditional experimental designs (Inouye 2001). The applications of RSM have been very helpful and extensively used in the industry (e.g., food manufacturing, drug manufacturing, etc.) where the relationship between the response and the design factors are approximated by some low-order polynomials. Aslan (2008) used RSM in a central composite design (CCD) for modeling and optimization of influence of operating variables on performance of multigravity separator for chromite concentration. Similarly, Li et al. (2008) used RSM for the design optimization of integrated circuits. On the other hand, Hsu (1995) also used RSM to study the effect of processing variables on the quality of frozen surimi. RSM is useful not only in product design but also in systems modeling in biology and ecology. Inouye (2001) used simulated data in comparing the ability of six different response surface designs to estimate correctly the competition coefficients of simple competition models under a variety of conditions. There are also applications in the physical sciences, biological sciences, as well as social sciences (see for example Khuri and Cornell 1987).

As an empirical strategy, RSM aims to choose designs that are simple and results are easily interpretable. The optimal design that is desirable in RSM is usually evaluated based on two very important characteristics: orthogonality and rotatability. Orthogonal designs result to uncorrelated terms in the model, hence parameter estimates are uncorrelated as well (Khuri and Cornell 1987). A first-order orthogonal design is ideal in least squares estimation since the design matrix X'X is diagonal and hence, interpretation of the regression coefficients is simplified because the effects are additive and not conditional on other terms in the model. According to Myers and Montgomery (2002), the orthogonality of the design matrix X implies that the roles of two variables can be assessed independently of each other. Rotatable designs, on the other hand, yield the same prediction variance $V(\hat{y}(x))$ at all points x that are equidistant from the center point. The desirable feature is that quality of prediction is invariant to any rotation of the coordinate axes in the space of predictor variables (Khuri and Cornell 1987). As noted by Myers and Montgomery (2002), a rotatable design will not require knowledge of the exact location of the optimum point (for as long as it is within the design space) before the experiment is conducted.The CCD results to design points that possess both the properties of orthogonality and rotatability.

In recent modeling paradigms, the additive model was introduced where the response variable is expressed as a sum of functions of predictors. The form of the function is not necessarily specified, but the usual linear smoother may also be considered. Since each component of the model has an additive effect to the response, it facilitates the piecewise estimation of each component. The effect of one component is estimated by regressing the response on the particular variable, the next variable is regressed on the residuals from the first, and so on, until all components are accounted. This estimation method called backfitting yields many computational advantages (see Hastie and Tibshirani 1990 for details). Given an additive model, the backfitting algorithm examines the effect of each variable/component individually, hence unlike the maximum likelihood estimation, it is not flooded with parameters being estimated thereby affecting the speed of convergence. In the case of least squares estimation in every stage, the design matrix will have a “better configuration” since it is already low-dimensional and this avoids the ill-conditioning problem.

This ensures the stability of the resulting least squares estimators in the backfitting algorithm.

In RSM, there are generally very few design points that are used to generate responses since cost of experimentation is often prohibitive. With very few points, the configuration of the design matrix can be prone to ill-conditioning, hence stability of the parameter estimates might be threatened. Since a CCD generates orthogonal points, this can easily satisfy the additivity of the components in an additive model, hence backfitting can potentially mediate in the balance between cost (fewer design points) and stability of parameter estimates.

In some response surface experiments, multicollinearity can be present among the design factors (especially since there are only very few design points) and this can have serious effects on the stability of estimated parameters and on the usefulness of the estimated model if ordinary least squares is used in fitting the model (see Carley et al. 2004 for detailed discussion). Multicollinearity is also easily observed in experiments with high dimensions, i.e., too many design factors. In the presence of multicollinearity, the fitted model may still be useful despite the imprecision of the estimated regression coefficients, but predictions of new observations requiring extrapolation beyond the experimental region can yield poor results.

This paper proposes to use backfitting in estimating a response surface model with covariates in a CCD. Through a simulation study, the accuracy of the parameter estimates will be assessed along with the predictive ability of the estimated response surface.

We would like to provide an alternative estimation procedure to ordinary least squares when the postulated model does not fit the data well, e.g., when there is too much bias in the approximate response surface function. Backfitting can 'optimize' the extraction of signals from the response and hence, minimizes the remaining noise that is unaccounted for. The method can also handle contamination and possibly misspecification that may occur during experimentation and during the response surface estimation. Robustness of the method is feasible because of the orthogonality of the design matrix generated from the Central Composite Design.

2. Alternative Estimation of the Response Surface

As Khuri and Cornell (1987) defined it, a central composite design consists of: (1) a complete (or fraction of a) 2^k factorial design, where the factor levels are coded -1, +1 values. This is called the factorial portion of the design; (2) n_0 center points ($n_0 \geq 1$); (3) two axial points on the axis of each design variable at a distance of α from the design center. This is called the axial portion of the design. Myers and Montgomery (2002) gave the roles of these three components of the design. A variance-optimal design for a first order model or first-order with two factor interaction model is what the factorial points represent. On the other hand, information about the existence of a curvature in the system is what the center point runs provide. Moreover, axial points contribute to the efficient estimation of the pure quadratic terms if a curvature exists in the system.

Among the designs commonly used in response surface modeling, CCD is popular since it implies two desirable properties: othogonality and rotatability. Orthogonality facilitates the attainment of many optimal characteristics of least squares method. Draper and Smith (1998) discusses the implications of orthogonality of columns of X. Suppose the data matrix is partitioned into $X=(X_1,X_2)$ and if $X_1X_2=0$, then in the model $Y = X_1\beta_1 + X_2\beta_2 + \varepsilon$, $\hat{\beta}_1 = (X_1{}'X_1)^{-1}X_1Y$, and $\hat{\beta}_2 = (X_2{}'X_2)^{-1}X_2Y$ and $SS(\hat{\beta}) = SS(\hat{\beta}_1) + SS(\hat{\beta}_2)$. This implies that the contribution of X_1 and X_2 in explaining Y may be separately assessed without affecting the other block of independent variables. The model is necessarily additive.

Benefitting from the orthogonality of the design matrix from the CCD, the response surface model is additive. Thus, the backfitting algorithm that performs best in an additive model can simplify the estimation of the parameters of the response surface model. Opsomer (2000) shows that if covariates are independent, then the asymptotic bias of the linear smoother obtained through a backfitting algorithm becomes very small. This implies that if for instance, the response surface is approximated by the second-order model, the order bias of the approximation is minimal when the model is estimated through linear smoothing in a backfitting algorithm. Butler (2006) further noted the minimum response surface bias in CCD for any number of center points.

Given a data from a CCD, the following backfitting algorithm in a linear smoother is proposed to estimate the response surface model with covariates.

Step 1: Postulate an additive model of the form

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots + \beta_kX_k + \delta_1Z_1 + \delta_2Z_2 + \ldots + \delta_jZ_j + \varepsilon \quad (1)$$

or a second-order model of the form

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_{11}X_1^2 + \ldots + \beta_{kk}X_k^2 + \beta_{12}X_{12} + \ldots + \beta_{kj}X_{kj} + \delta_1Z_1 + \delta_2Z_2 + .. + \delta_jZ_j + \varepsilon \quad (2)$$

Step 2: Estimate a regression model with the first factor X_1 using ordinary least squares. Compute the residual $e_1 = y - \hat{\beta}_0 - \hat{\beta}_1x_1$ from the estimated regression coefficients.

Step 3: Regress the residual e_1 with X_2. Compute the remaining residual left by taking out the effect of X_2. Continue iteration until the effect of the last factor is accounted and the remaining residuals can be attributed to the covariates.

Step 4: The covariate with the highest correlation with the response variable will be regressed with the residual left in Step 3. Continue with the estimation of the covariate effect until all covariates are included in the model, the last set of residuals are attributed to pure error.

Aside from taking advantage of the additivity of the response surface model, the backfitting algorithm will also facilitate estimation of the model when there are many factors and covariates involved since CCD is expected to require few design points only.

3. Simulation Study

A simulation study is presented to illustrate the relative advantage of the proposed estimation procedure for a response surface model. The data generation process is expected to mimic a response surface setting that enables fitting of the first- or second-order models.

The 'true' response functions assumed are given by the following:

Model 1: $y = 1 - 0.1x_1 + 0.01x_2 - 0.01z_1 - 0.01z_2 + k\varepsilon$ (3)

Model 2: $y = 1 - 0.1x_1 + 0.001x_2 - 0.01z_1 - 0.01z_2 + 0.001w + k\varepsilon$ (4)

where x_1 and x_2 are the factors, z_1 and z_2 are covariates, w is another variable that also affects the response variable but will be assumed later as not accessible to the experimenter, k is a constant to be used in inducing contamination that controls the correlation of the factors with the response variable, and ε is the error term.

These models can generate scenarios of ideal response surface modeling situations as well as those with misspecifications. We simulated two types of misspecifications. Data coming from model (3) illustrates misspecification in terms of assumption on errors while data from model (4) will show the misspecification through variable omission when w is left out during the estimation and pretend that it is part of the error. The error terms are used in simulating the misspecification reflected as violation of the usual regression assumption, e.g., normal distribution.

For the 'true' model, two error term distributions (normal and poisson) are considered. The normal distribution cases are N(0,1), N(0,100), and N(100,100), while the poisson distributions are Po(10), and Po(100). The normal distribution for simulated error terms is important because in ordinary least squares regression, this will ensure the validity of the Gauss-Markov theorem. The case N(0,1) illustrates most ideal scenario, N(0,100) for highly heteroskedastic errors, possibly due to outlying random shocks. The last distribution of error terms represents the case where there is misspecification in the assumptions related to the error distribution. Po(10) represents a skewed discrete error with a smaller mean and variance while Po(100) illustrates a scenario of error terms coming from a skewed population with larger mean and variance. When the response variable is count, a skewed distribution may best characterize the behavior of the error term. The choice of the distribution of error terms having varying variances and means will also illustrate the presence of contamination in the experimentation. In controlled experiments, responses and experimental errors are expected to exhibit smaller variances within the same setting. Variances become larger when certain experimental conditions are not properly controlled. Scenarios of different levels of contamination constant *k* (high, moderate, and low) are also included in the simulation by multiplying it to the error terms. The contamination constant *k* controls the correlation of the response variable and the factors. Lower values of *k* mean higher correlation between the response and the predictor variables. Low values of *k* illustrate the case that data coming from models (3) and (4) can potentially lead to good model fit while higher levels of *k*, can lead to either moderate to poor model fit. Higher coefficient of determination (R^2) implies that ordinary least squares (OLS) is optimal by the virtue of Gauss–Markov Theorem under some regularity conditions on the error distribution. Conversely, low R^2 means poor model fit, perhaps due to misspecification, or inappropriate model, which leads to failure of OLS estimates. In RSM which is associated with high data generation cost, a more robust procedure is needed.

In all the scenarios, two factors, X_1 and X_2, are simulated based on the pre-specified range of values $6<X_1<11$ and $100<X_2<300$. These values are chosen to induce variation into the predictor variables to facilitate estimation of the response surface. The first variable has a smaller range compared to the second to imitate certain characteristics of factors that are commonly used. The choice of having a shorter range of values for X_1 illustrates the instance where short range of values for one factor easily causes multicollinearity to manifest.

There are four possible combinations of distributions from which these factors are simulated from: two continuous probability distributions, two discrete probability distributions, a combination of a discrete and a continuous probability distribution, i.e., 1) N(9,1) , N(200, 961) ; 2) Po(8), Po(200); 3) N(9,1), Po(200); and 4) Po(8), N(200,961). Normal distribution is considered for the continuous case to illustrate the scenario that the factor comes from a symmetric continuous distribution. On the other hand, a skewed discrete population is illustrated by considering the poisson distribution usually for count data.

The covariates Z_1 and Z_2 are generated from N(0,1) and N (0,100), respectively. The covariates are simulated to capture instances where uncontrollable factors are present in the experiment.

A population of 1,000 observations is simulated from each of the 120 simulation scenarios, see Table 1. Twenty datasets are generated for each of these populations. The CCD points (there are 9 points of these including the axial point, 2^k points, and a center point) are added within each set of the Xs to come up with 1000 observations. These CCD points are computed based on the means and standard deviations of X_1

and X_2, respectively, using the transformation $x^* = \frac{X - \overline{X}}{sd}$, where x* is the coded value of the factor levels and X is the natural value of the factor. The remaining 991 observations are generated from the corresponding sets of combinations of distributions mentioned above.

From these 1,000 observations, random samples of size 9, using simple random sampling without replacement (SRSWOR) is also drawn. Only nine sample points are chosen to facilitate comparison with CCD points.

The parameters of the true models (coefficients) summarized in Table 1 are arbitrarily chosen. The response variable y is computed using Models 1 and 2. Ordinary least squares regression is used to estimate the Model 1. Model 2 is also estimated with ordinary least squares but the variable w is intentionally deleted to simulate a case where a factor is missed out so that response surface bias is introduced. The estimation is also done using all 1,000 observations. For each of the datasets, we pick out 1) CCD points, and 2) random samples obtained from simple random sampling without replacement. Then OLS regression to the CCD points and random sample points are also implemented. Backfitting was used in estimating the response surface using the CCD points and to the random samples.

Table 1. Simulation scenarios

Model 1														
N(0,1)			N(0,100)			N(100,100)			Po(10)			Po(100)		
H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN
PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP
Model 2														
N(0,1)			N(0,100)			N(100,100)			Po(10)			Po(100)		
H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN	PN
PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP

Note: H-High values of k; M-Moderate values of k; L – Low values of k
NN - X_1~N(9,1), X_2~N(200,961), Z_1~N(0,1), Z_2~N(0,100)
NP - X_1~N(9,1), X_2~Po(200), Z_1~N(0,1), Z_2~N(0,100)
PN - X_1~Po(8), X_2~N(200,961), Z_1~N(0,1), Z_2~N(0,100)
PP - X_1~Po(8), X_2~Po(200), Z_1~N(0,1), Z_2~N(0,100)

The mean absolute percentage error (MAPE), which is the average of the absolute value of the quotient of the residual and the response variable multiplied by 100%, i.e. MAPE = average | [(y- $\hat{y}$)/y] *100%| , is used to evaluate the predictive ability of the estimated models obtained from backfitting. The MAPE values obtained using the backfitting of CCD points and SRS points are compared to that of the

MAPE values of the original population which used OLS in estimation. The relative advantage of backfitting will already manifest once it yield comparable performance in predicting responses to that of the actual population. Note that the proposed estimation method tend to set aside the effect of other factors while estimating others, hence, it may not be attractive at the start, but as the number of experimental factors increases, it will manifest the computational advantage.

3.1 Predictive ability

The MAPE computed from the 20 datasets simulated from Model 1 with low and high values of contamination constant *k* and having normally distributed error terms are summarized in Tables 2 to 4. High and low values of k illustrate how the estimation procedure will perform compared to OLS when the model fits the data well/poorly. In Table 2 where there is no misspecification and the error term behaves as N(0,1), the OLS provides MAPE very close to the MAPE obtained when the entire population is used in estimating the parameters. OLS is clearly optimal since all the requirements for the Gauss-Markov Theorem to hold is present. Models with parameters estimated from backfitting yield inferior predictive ability compared to OLS. However, even for the case where the error term is N(0,1), the backfitting algorithm shows slight advantage over OLS when model fit is poor (contaminated errors). The varying combination of distributions where the factors are generated from does not necessarily influence predictive ability of the model whether using OLS or backfitting or whether there is a good or poor model fit to the data.

Table 2. Average MAPE of datasets simulated from model 1 with error term N (0,1)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.999	0.998	0.999	0.999	R^2	0.11	0.041	0.1749	0.0995
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		0.39	0.38	0.38	0.37		229.80	251.31	142.82	176.42
OLS_{CCD}		0.53	0.64	0.55	0.55		242.85	431.18	155.76	215.67
BF_{CCD}		15.47	7.15	15.75	6.34		268.90	405.25	166.45	207.42
OLS_{SRS}		0.59	0.62	0.56	0.53		241.60	297.02	182.61	206.72
BF_{SRS}		15.09	7.90	15.05	6.88		275.06	269.87	187.14	181.43

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population data
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

In Table 3, as the variance of the error distribution increases, the predictive ability of the model estimated from backfitting changes. Even with good model fit, models estimated using backfitting yield comparable MAPE to those estimated using OLS. When model fit worsen (still with large error variance), the advantage of backfitting becomes clearer. The MAPE produced by models estimated using backfitting are comparable to the MAPE when the entire population data is used. Those MAPE coming from OLS–estimated models are way higher than the MAPE when the model is estimated using the entire population data.

Table 3. Average MAPE of datasets simulated from model 1 with error term N(0,100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.9211	0.801	0.951	0.916	**R^2**	0.0053	0.00421	0.00658	0.00489
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		3.94	3.86	3.80	3.71		230.97	252.82	389.13	633.14
OLS_{CCD}		5.37	6.39	5.54	5.56		735.00	780.64	727.00	932.45
BF_{CCD}		16.57	9.29	16.80	8.22		619.36	631.82	628.89	688.06
OLS_{SRS}		5.78	5.91	6.04	5.73		792.27	713.67	945.66	1351.67
BF_{SRS}		16.54	8.76	20.28	8.89		602.22	591.71	1020.33	686.88

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

In Table 4, where aside from large error variance, mean is also nonzero, the predictive ability of OLS and backfitting are comparable to the predictive ability of a model estimated using the entire population data. This observation is valid whether there is good or poor model fit.

With poisson error distribution with lower mean, the backfitting estimates yield models that predict with similar reliability to OLS. The advantage of OLS over backfitting for models with good fit is no longer that remarkable. And as the model fit deteriorates, backfitting becomes more accurate over OLS in predicting responses. Similar is also true even when the mean (variance) of the poisson distribution increases further (see Table 6 for details). In Table 7, while the error term is N(0,1), a predictor is intentionally missed out in the estimation to simulate a scenario where there is omitted variable. For the case where there is a good model fit, OLS is only slightly advantageous over backfitting. When model fit declines, backfitting exhibits advantages over OLS. Similar is true when the variance of the error distribution increases (see Table 8 for details) or when aside from large variance, mean of error distribution is also nonzero (see Table 9 for details).

Table 4. Average MAPE of datasets simulated from model 1 with error term N(100,100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.921	0.801	0.951	0.916	**R^2**	0.0053	0.00421	0.0066	0.0049
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		2.62	2.60	2.54	2.51		7.99	7.99	7.92	7.92
OLS_{CCD}		3.55	4.29	3.68	3.75		10.72	13.17	11.42	11.76
BF_{CCD}		10.90	6.23	11.03	5.54		10.03	10.88	10.38	10.57
OLS_{SRS}		4.09	4.69	4.09	3.58		10.91	12.34	11.24	11.79
BF_{SRS}		11.73	6.30	11.12	6.01		9.69	9.91	10.19	10.52

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 5. Average MAPE of datasets simulated from model 1 with error term Po(10)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.99	0.98	0.99	0.99	**R^2**	0.02	0.007	0.025	0.016
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		1.17	1.16	1.13	1.11		23.52	23.68	23.04	23.04
OLS_{CCD}		1.75	1.77	1.68	1.51		30.70	35.20	33.26	31.22
BF_{CCD}		14.19	6.87	13.28	6.52		28.48	32.86	30.40	28.62
OLS_{SRS}		1.90	1.76	1.66	1.65		31.60	35.60	36.49	31.55
BF_{SRS}		14.73	7.21	15.05	7.09		30.83	29.66	31.12	28.97

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 6. Average MAPE of datasets simulated from model 1 with error term Po(100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.92	0.801	0.951	0.92	**R^2**	0.005	0.004	0.007	0.005
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		2.62	2.60	2.54	2.51		8.00	7.99	7.92	7.92
OLS_{CCD}		3.55	4.30	3.68	3.76		10.78	13.18	11.41	11.78
BF_{CCD}		10.90	6.22	11.03	5.55		10.02	10.88	10.37	10.59
OLS_{SRS}		4.27	4.84	3.83	4.16		11.95	11.81	11.00	10.74
BF_{SRS}		11.08	6.23	10.58	5.93		10.22	10.55	9.72	9.48

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 7. Average MAPE of datasets simulated from model 2 with error term N (0,1)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.95	0.99	0.989	0.997	**R^2**	0.022	0.022	0.0853	0.0834
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		6.05	3.38	31.41	5.27		414.79	334.08	14804.54	516.10
OLS_{CCD}		8.71	4.48	42.86	8.01		720.37	661.85	4614.44	775.82
BF_{CCD}		10.00	5.94	41.59	14.55		684.90	556.59	13343.80	720.41
OLS_{SRS}		9.04	5.17	29.59	9.55		778.91	593.15	5140.77	1174.39
BF_{SRS}		12.11	6.48	113.71	16.78		562.08	565.26	6569.49	897.44

Note:NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 8. Average MAPE of datasets simulated from model 2 with error term N(0,100)

		Low k					High k			
Method	**k**	0.001	0.001	0.001	0.001	**k**	1.00	1.00	1.00	1.00
	R^2	0.95	0.99	0.99	1	**R^2**	0.0038	0.004	0.004	0.005
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		6.05	3.38	31.41	5.27		181.11	137.50	144.79	134.73
OLS_{CCD}		8.71	4.48	42.86	8.01		690.97	581.91	688.22	560.83
BF_{CCD}		10.00	5.94	41.59	14.55		586.34	463.18	543.12	502.59
OLS_{SRS}		9.02	4.93	45.91	8.93		975.46	717.75	813.93	665.67
BF_{SRS}		12.05	6.16	47.17	12.10		1021.92	547.97	682.24	550.21

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 9. Average MAPE of datasets simulated from model 2 with error term N(100,100)

		Low k					High k			
Method	**k**	0.001	0.001	0.001	0.001	**k**	1.00	1.00	1.00	1.00
	R^2	0.95	0.99	0.989	0.997	**R^2**	0.004	0.004	0.004	0.005
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{POPN}		4.70	2.49	8.46	4.56		8.07	8.11	8.08	8.12
OLS_{CCD}		6.77	3.26	15.18	6.55		11.48	11.79	11.04	10.63
BF_{CCD}		7.73	4.34	16.87	9.98		10.30	10.27	9.80	9.98
OLS_{SRS}		6.65	3.75	15.80	7.20		11.58	10.92	10.99	11.93
BF_{SRS}		9.10	5.96	27.85	8.82		10.11	10.28	10.01	9.96

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

In Tables 10 and 11, in addition to a missed factor, the errors are also coming from a skewed distribution (poisson). Again, when the model fits the data well, the predictive ability of models with parameters estimated using backfitting is comparable to those estimated using OLS. And as fit of the model deteriorates, backfitting becomes more advantageous (better predictive ability).

Table 10. Average MAPE of datasets simulated from model 2 with error term Po (10)

Method		Low k					High k			
	k	0.01	0.01	0.01	0.01	k	1.00	1.00	1.00	1.00
	R^2	0.92	0.94	0.979	0.99	R^2	0.01	0.01	0.01	0.01
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	NP	PN	PP		NN	NP	PN	PP
OLS_{POPN}		6.37	4.96	21.75	10.39		28.41	28.68	28.48	28.13
OLS_{CCD}		9.52	7.83	28.74	23.73		37.51	42.83	38.67	37.76
BF_{CCD}		11.60	8.10	105.92	26.27		34.85	39.01	35.53	37.46
OLS_{SRS}		11.56	6.48	36.74	19.24		37.36	47.09	43.01	42.31
BF_{SRS}		12.97	6.69	52.08	22.65		33.20	37.36	39.19	33.17

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 11. Average MAPE of datasets simulated from model 2 with error term Po (100)

Method		Low k					High k			
	k	0.001	0.001	0.001	0.001	k	1.00	1.00	1.00	1.00
	R^2	0.95	0.99	0.989	0.997	R^2	0.004	0.004	0.004	0.005
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	NP	PN	PP		NN	NP	PN	PP
OLS_{POPN}		4.70	2.49	12.98	5.11		8.07	8.11	8.08	8.13
OLS_{CCD}		6.77	3.26	24.61	7.25		11.48	11.85	11.06	10.65
BF_{CCD}		7.73	4.34	26.53	10.70		10.32	10.27	9.82	10.00
OLS_{SRS}		7.39	3.81	20.27	6.36		11.04	12.13	12.22	13.46
BF_{SRS}		9.07	4.42	31.12	13.10		10.25	10.69	10.38	11.43

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSPOPN - OLS is used in estimation using the actual simulated population
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

It is clear that when backfitting is used in estimating parameters of a response surface model, the fitted model exhibits robustness to various nuisances associated with experimentation and model fitting. Contamination may occur during the experimentation stage to generate data that will be used in fitting the response surface model. Furthermore, some important predictors may be missed out in the desire to limit the number of factors to be included in the experiment. As a result, a model that poorly fits the data may be achieved. This will provide a poor approximation of the true response surface. If instead, backfitting is used in estimation, even with such problems with data-generation and model fitting, we can still expect a model that approximates the true response surface fairly well.

3.2 Parameter estimates

We summarize in Tables 12 to 14 the average percent difference between the parameter estimates from the 20 datasets using Model 1 with normal error terms and the true parameter values. When the model fits the data well, regardless of mean and variance values of the error distribution, backfitting provides estimates that are too far from the actual parameters compared to the estimates obtained using OLS. The optimality of OLS is again exhibited as it produced estimates that are very close to the true parameter values, see Table 12 for details. However, as the model fit deteriorates, regardless of the error distribution parameters, backfitting with both CCD points and SRS points are more advantageous over OLS in terms of parameter estimates. Backfitting was able to estimate parameters and are relatively closer to the actual parameters of the population than the estimates obtained using OLS. In the case where the error terms have large variance, the estimates obtained using backfitting with SRS points, given that a factor was generated from poisson distribution, the other, from normal distribution, are relatively far from the true parameter values. This can be explained by the kind of samples obtained in simple random sampling selection. Unlike the CCD which generated data that are predetermined or fixed before experimentation, SRS generates data that may vary as caused by sampling error. It is for this reason, that in addition to the desirable characteristic of CCD (orthogonality), backfitting is proposed as an estimation algorithm for a more robust approximation of the response surface.

Table 12. Average percent difference of parameter estimates from model 1 with error term N(0,1)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.9992	0.9975	0.9995	0.9991	R^2	0.10997	0.04099	0.17487	0.09947
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		8.84	17.01	10.34	10.84		799.59	2301.73	1805.58	2392.49
BF_{CCD}		366.63	222.10	383.65	190.21		779.53	1225.95	1396.59	1604.71
OLS_{SRS}		9.63	13.71	9.26	8.29		1218.88	927.71	2308.28	2532.44
BF_{SRS}		291.69	209.60	263.75	162.00		964.82	838.42	1548.84	1810.07

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 13. Average percent difference of parameter estimates from model 1 with error term N(0,100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.921	0.8013	0.951	0.916	**R^2**	0.0053	0.0042	0.00658	0.0049
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		89.81	183.23	98.39	109.88		4396.60	6050.12	23235.92	3641.40
BF_{CCD}		392.99	321.08	415.56	221.21		3781.39	2555.76	17658.38	2799.82
OLS_{SRS}		107.44	90991.62	97.47	94.42		5781.15	5037.46	10951.15	4147.73
BF_{SRS}		309.71	271.47	354.90	171.30		3931.35	2979.18	16957.24	2027.08

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 14. Average percent difference of parameter estimates from model 1 with Error term N(100,100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.921	0.801	0.951	0.916	**R^2**	0.0053	0.00421	0.00658	0.0049
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		85.29	177.16	95.74	104.41		3933.09	5539.17	21828.61	3097.86
BF_{CCD}		372.15	301.08	395.25	202.18		3366.91	2206.82	17032.69	2688.39
OLS_{SRS}		129.52	229.79	100.00	74.60		3620.56	3645.03	11788.54	3998.69
BF_{SRS}		359.72	246.48	227.53	202.20		2661.64	1621.96	21044.95	2984.56

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

When the error distribution is poisson and the model fits the data well, with lower mean/variance, backfitting yields inferior estimates over those obtained using OLS. However, backfitting yield better estimates than OLS when the model fits the data poorly. In Table 15, the varying combination of distributions where the factors were generated from, does not necessarily influence the quality of estimates whether using OLS nor backfitting. Noticeably, when model fit is not good, and among the four combinations of distributions that factors generated come from the combination of factors 1 and 2 coming from poisson distribution illustrates the optimality of the backfitting estimation.

Table 15. Average percent difference of parameter estimates from model 1 with error term Po(10)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.9915	0.97531	0.99482	0.99092	**R^2**	0.01595	0.00694	0.0252	0.01592
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		32.27	41.77	33.64	28.88		2254.86	3172.71	4125.48	1099.66
BF_{CCD}		329.24	186.83	267.91	203.82		1949.41	2677.98	3412.17	669.85
OLS_{SRS}		40.78	39.39	34.30	39.84		2010.85	3091.18	4803.45	987.43
BF_{SRS}		311.01	168.40	308.20	173.28		1582.22	2678.05	2564.43	622.90

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

In Table 16, good model fit again exhibited the advantage of OLS over backfitting. In some extreme cases (high variance), the estimates from backfitting can be comparable to the estimates obtained using OLS. Evidences of backfitting yielding better estimates over OLS is clearly seen when model fit deteriorates. Except for a missed out variable, when the model fit is good and under the most ideal setting N(0,1), OLS and backfitting produced comparable estimates of the parameters. This is also true for the other cases of normal error distribution but with large variance, see Tables 18-19 for details. The advantages of backfitting over OLS manifests when the model fits the data poorly, see Tables 17-19.

Table 16. Average percent difference of parameter estimates from model 1 with error term Po(100)

		Low k					High k			
Method	**k**	0.01	0.01	0.01	0.01	**k**	1.00	1.00	1.00	1.00
	R^2	0.92101	0.80118	0.95107	0.91603	**R^2**	0.00528	0.004215	0.006625	0.004875
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		85.28	178.38	96.04	105.02		7704.86	3460150.13	4083.97	3782.31
BF_{CCD}		372.37	303.43	396.97	202.78		6980.75	3895.80	3134.18	3341.43
OLS_{SRS}		122.78	152.74	113.25	148.71		11720.58	1327091.84	7438.18	2355.14
BF_{SRS}		278.12	162.22	252.34	217.32		2623.10	6641.87	5508.30	1608.18

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 17. Average percent difference of parameter estimates from model 2 with error term N(0,1)

	Low k					High k			
Method k	0.01	0.01	0.01	0.01	**k**	1	1	1	1
R^2	0.95154	0.985385	0.9886	0.996665	**R^2**	0.022245	0.02176	0.0853	0.083395
	Combination of X_1 and X_2					**Combination of X_1 and X_2**			
	NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}	33.84	22.30	46.31	24.17		4130.28	1452.54	1283.38	2383.22
BF_{CCD}	42.26	44.21	71.13	73.30		1405.77	700.92	693.28	2869.53
OLS_{SRS}	42.20	28.52	37.16	30.86		2223.29	1069.18	1183.91	4821.04
BF_{SRS}	57.01	49.27	70.15	79.09		1071.87	704.52	832.88	3082.58

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using Central Composite Design points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 18. Average percent difference of parameter estimates from model 2 with error term N(0,100)

		Low k					High k			
Method	**k**	0.001	0.001	0.001	0.001	**k**	1.00	1.00	1.00	1.00
	R^2	0.95154	0.985385	0.9886	0.996665	**R^2**	0.003845	0.003845	0.00438	0.00487
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		33.84	22.30	46.31	24.17		5970.30	5834.56	250430.61	3382.12
BF_{CCD}		42.26	44.21	71.13	73.30		4464.05	3094.52	229988.12	2022.77
OLS_{SRS}		35.91	28.93	52.15	30.78		5806.98	11260.40	587003.62	3528.47
BF_{SRS}		63.25	45.97	73.66	55.17		2706.18	8910.14	582469.05	2019.23

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

With poisson error distribution and in addition, there is a predictor that is missed out, Tables 20-21 show the quality of the estimates obtained from backfitting are comparable to the quality of estimates obtained from OLS. The estimates of backfitting, on the other hand, are better than the estimates of OLS when the model does not fit the data well.

Table 19. Average percent difference of parameter estimates from model 2 with error term N(100,100)

Method		Low k					High k			
	k	0.001	0.001	0.001	0.001	k	1.00	1.00	1.00	1.00
	R^2	0.95154	0.9854	0.9886	0.9967	R^2	0.003845	0.00385	0.00438	0.00487
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	NP	PN	PP		NN	NP	PN	PP
OLS_{CCD}		33.68	22.21	46.22	24.07		4373.67	4961.82	128156.76	3069.41
BF_{CCD}		41.96	43.95	70.87	73.04		3128.60	2675.00	51341.24	1967.24
OLS_{SRS}		37.80	25.04	33.55	36.14		4697.38	5058.30	138150.07	9788.76
BF_{SRS}		69.15	56.62	97.80	59.52		3550.28	3304.00	7074.23	5553.65

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

Table 20. Average percent difference of parameter estimates from model 2 with error term Po(10)

Method		Low k					High k			
	k	0.01	0.01	0.01	0.01	k	1.00	1.00	1.00	1.00
	R^2	0.9173	0.9444	0.97923	0.98687	R^2	0.00718	0.00531	0.01086	0.01237
		Combination of X_1 and X_2					Combination of X_1 and X_2			
		NN	NP	PN	PP		NN	NP	PN	PP
OLS_{CCD}		58.73	54.51	54.38	47.77		2741.20	41217.70	2331.33	1141.52
BF_{CCD}		95.43	59.61	100.92	93.71		1524.67	36497.88	1344.01	883.94
OLS_{SRS}		102.46	39.53	68.61	59.50		2439.04	27277.03	3879.13	2570.62
BF_{SRS}		118.52	46.07	89.73	58.20		1147.31	24498.41	2783.32	842.17

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

The different scenarios illustrated that when there is contamination (e.g., error distribution, missed out factor) in the data and in the process of response surface estimation, backfitting provides estimates that are relatively robust to such contaminations. The use of CCD to generate data in fitting the response surface is necessary to ensure orthogonality and subsequently, additivity of the response surface that will facilitate the implementation of the backfitting algorithm.

Table 21. Average percent difference of parameter estimates from model 2 with error term Po(100)

		Low k					High k			
Method	**k**	0.001	0.001	0.001	0.001	**k**	1.00	1.00	1.00	1.00
	R^2	0.95154	0.98538	0.988595	0.99666	**R^2**	0.003815	0.00386	0.004335	0.004885
		Combination of X_1 and X_2					**Combination of X_1 and X_2**			
		NN	**NP**	**PN**	**PP**		**NN**	**NP**	**PN**	**PP**
OLS_{CCD}		33.61	22.30	46.16	23.99		7217.73	6374.97	5405.40	2746.09
BF_{CCD}		41.96	43.98	70.86	73.03		5506.84	2485.53	2874.34	1733.80
OLS_{SRS}		49.37	31.78	47.54	21.94		11667.60	5226.17	12279.07	6660.86
BF_{SRS}		63.95	42.36	103.57	59.91		7075.23	1953.64	9483.85	6362.91

Note: NN - X1~N(9,1), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
NP - X1~N(9,1), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
PN - X1~Po(8), X2~N(200,961), Z1~N(0,1), Z2~N(0,100)
PP - X1~Po(8), X2~Po(200), Z1~N(0,1), Z2~N(0,100)
OLSCCD - OLS is used in estimation using CCD points
OLSSRS - OLS is used in estimation using simple random sample points
BFCCD- Backfitting is used in estimation using CCD points
BFSRS- Backfitting is used in estimation using simple random sample points

4. Conclusions

The simulation study shows that when the model fits fairly well to the data, backfitting is comparable to ordinary least squares in estimating a response surface model. Backfitting, as an iterative procedure, works well under cases where severe misspecification in the model is present, possibly caused by contamination in the course of experimentation. These problems like omission of variables, error assumption, or experimental contamination, all leading towards failure of OLS to approximate the response surface. Backfitting is robust to various nuisances in experimentation that usually generates data used in fitting a response surface. When the fitted response surface is prone to bias due to high dimensionality of operating variables, backfitting can intervene in the estimation, provided that a design leading to an orthogonal design matrix is used.

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The Random Component of the Levy Fractional Brownian Motion: A Rotation-Scale-Reflection-Invariant Random Field

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This paper shows that the Levy fractional Brownian motion (LFBM) on the plane can be expressed as a product of two components, one being a deterministic trend term and the other being a rotation-scale-reflection-invariant (RSRI) random field. An important consequence of this characterization is that one can study the LFBM by establishing the properties of the associated RSRI random field.

Keywords: Levy fractional Brownian motion, rotation-scale-reflection-invariant random field

1. Introduction

The Levy fractional Brownian motion (LFBM) is a self-similar random field that is important both in the theory of stochastic processes and in practical applications (Adler 1981). Letting $\Re_{\mathbf{0}}^2$ denote the two-dimensional Euclidean plane excluding the origin, the LFBM on $\Re_{\mathbf{0}}^2$, say $\mathbf{Y} \equiv \{Y(\mathbf{s}) : \mathbf{s} \in \Re_{\mathbf{0}}^2\}$, is defined as a Gaussian random field having a mean function identically zero and a covariance function that satisfies

$$Cov[Y(\mathbf{s}), Y(\mathbf{t})] = \frac{\|\mathbf{s}\|^{2H} + \|\mathbf{t}\|^{2H} - \|\mathbf{s} - \mathbf{t}\|^{2H}}{2} \qquad (1.1)$$

for all $\mathbf{s}, \mathbf{t} \in \Re_{\mathbf{0}}^2$, where $H \in (0,1)$.

This paper shows that the LFBM can be written as the product of a deterministic term and a random component, with the latter turning out to be a rotation-scale-reflection-invariant (RSRI) random field. A RSRI random field in the weak sense is defined as having a mean function that is constant and a covariance function that depends only on the angle and norm ratio between points on the plane. More specifically, for any pair of points $\mathbf{s},\mathbf{t} \in \Re_{\mathbf{0}}^2$ let $\theta_{\mathbf{s},\mathbf{t}} \in [0,\pi]$ be the ordinary positive angle measure between $\mathbf{s}$ and $\mathbf{t}$ with vertex the origin, and

$$\phi_{\mathbf{s},\mathbf{t}} = \min\left\{\frac{\|\mathbf{s}\|}{\|\mathbf{t}\|}, \frac{\|\mathbf{t}\|}{\|\mathbf{s}\|}\right\}$$

be the minimal norm ratio between $\mathbf{s}$ and $\mathbf{t}$. Then the covariance function of a RSRI random field, say $\mathbf{X} \equiv \{X(\mathbf{s}) : \mathbf{s} \in \Re_{\mathbf{0}}^2\}$, is such that for all $\mathbf{s},\mathbf{t} \in \Re_{\mathbf{0}}^2$,

$$Cov[X(\mathbf{s}), X(\mathbf{t})] = R(\theta_{\mathbf{s},\mathbf{t}}, \phi_{\mathbf{s},\mathbf{t}}) \tag{1.2}$$

where the function R depends on $\mathbf{s}$ and $\mathbf{t}$ only through $\theta_{\mathbf{s},\mathbf{t}}$ and $\phi_{\mathbf{s},\mathbf{t}}$ (Tejada 2008).

One consequence of this correspondence between the LFBM and its associated RSRI random field is that the study of the former may be conducted by a study of the latter. In particular, properties of the LFBM could be derived by first examining those of the RSRI random field. This approach is especially beneficial if the characteristics of the RSRI random field are easier to establish than those of the LFBM.

2. Main Result

Proposition: Let the random field $\mathbf{Y} \equiv \{Y(\mathbf{s}) : \mathbf{s} \in \Re_{\mathbf{0}}^2\}$ be the LFBM on $\Re_{\mathbf{0}}^2$ with index $H \in (0,1)$. Then for every point $\mathbf{s} \in \Re_{\mathbf{0}}^2$,

$$Y(\mathbf{s}) = \|\mathbf{s}\|^H X(\mathbf{s}) \tag{2.1}$$

for some RSRI random field $\mathbf{X} \equiv \{X(\mathbf{s}) : \mathbf{s} \in \Re_{\mathbf{0}}^2\}$.

Proof: Since $\mathbf{Y}$ has a zero mean function, we have

$$\begin{aligned} E[X(\mathbf{s})] &= E\left[\|\mathbf{s}\|^{-H} Y(\mathbf{s})\right] \\ &= \|\mathbf{s}\|^{-H} E[Y(\mathbf{s})] \\ &= 0 \end{aligned}$$

so that $\mathbf{X}$ has a mean function identically equal to zero, a constant.

It is now shown that is RSRI, that is, its covariance function satisfies (1.2). First, observe that for any pair $\mathbf{s},\mathbf{t} \in \Re_{\mathbf{0}}^{2}$,

$$\phi_{\mathbf{s},\mathbf{t}} + \frac{1}{\phi_{\mathbf{s},\mathbf{t}}} = \min\left\{\frac{\|\mathbf{t}\|}{\|\mathbf{s}\|},\frac{\|\mathbf{s}\|}{\|\mathbf{t}\|}\right\} + \frac{1}{\min\left\{\frac{\|\mathbf{t}\|}{\|\mathbf{s}\|},\frac{\|\mathbf{s}\|}{\|\mathbf{t}\|}\right\}}$$

$$= \frac{\|\mathbf{s}\|}{\|\mathbf{t}\|} + \frac{\|\mathbf{t}\|}{\|\mathbf{s}\|} \tag{2.2}$$

Similarly, for any $H \in (0,1)$,

$$\phi_{\mathbf{s},\mathbf{t}}^{H} + \frac{1}{\phi_{\mathbf{s},\mathbf{t}}^{H}} = \frac{\|\mathbf{s}\|^{H}}{\|\mathbf{t}\|^{H}} + \frac{\|\mathbf{t}\|^{H}}{\|\mathbf{s}\|^{H}} \tag{2.3}$$

From (1.1) the covariance function of the LFBM $\mathbf{Y}$ can be derived as

$$Cov[Y(\mathbf{s}),Y(\mathbf{t})] = \frac{\|\mathbf{s}\|^{2H} + \|\mathbf{t}\|^{2H} - \|\mathbf{s}-\mathbf{t}\|^{2H}}{2}$$

$$= \left(\frac{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}{2}\right)\left(\frac{\|\mathbf{s}\|^{2H} + \|\mathbf{t}\|^{2H} - \|\mathbf{s}-\mathbf{t}\|^{2H}}{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}\right)$$

$$= \left(\frac{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}{2}\right)\left(\frac{\|\mathbf{s}\|^{2H}}{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}} + \frac{\|\mathbf{t}\|^{2H}}{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}} - \left(\frac{\|\mathbf{s}-\mathbf{t}\|^{2}}{\|\mathbf{s}\|\|\mathbf{t}\|}\right)^{H}\right)$$

$$= \left(\frac{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}{2}\right)\left(\frac{\|\mathbf{s}\|^{H}}{\|\mathbf{t}\|^{H}} + \frac{\|\mathbf{t}\|^{H}}{\|\mathbf{s}\|^{H}} - \left(\frac{\|\mathbf{s}-\mathbf{t}\|^{2} + \|\mathbf{s}\|^{2} + \|\mathbf{t}\|^{2} - \|\mathbf{s}\|^{2} - \|\mathbf{t}\|^{2}}{\|\mathbf{s}\|\|\mathbf{t}\|}\right)^{H}\right)$$

$$= \left(\frac{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}{2}\right)\left(\frac{\|\mathbf{s}\|^{H}}{\|\mathbf{t}\|^{H}} + \frac{\|\mathbf{t}\|^{H}}{\|\mathbf{s}\|^{H}} - \left(\frac{\|\mathbf{s}\|^{2} + \|\mathbf{t}\|^{2}}{\|\mathbf{s}\|\|\mathbf{t}\|} - \frac{\|\mathbf{s}\|^{2} + \|\mathbf{t}\|^{2} - \|\mathbf{s}-\mathbf{t}\|^{2}}{\|\mathbf{s}\|\|\mathbf{t}\|}\right)^{H}\right)$$

$$= \left(\frac{\|\mathbf{s}\|^{H}\|\mathbf{t}\|^{H}}{2}\right)\left(\frac{\|\mathbf{s}\|^{H}}{\|\mathbf{t}\|^{H}} + \frac{\|\mathbf{t}\|^{H}}{\|\mathbf{s}\|^{H}} - \left(\frac{\|\mathbf{s}\|}{\|\mathbf{t}\|} + \frac{\|\mathbf{t}\|}{\|\mathbf{s}\|} - \frac{\|\mathbf{s}\|^{2} + \|\mathbf{t}\|^{2} - \|\mathbf{s}-\mathbf{t}\|^{2}}{\|\mathbf{s}\|\|\mathbf{t}\|}\right)^{H}\right)$$

Using (2.2) and (2.3) as well as the cosine formula

$$\theta_{\mathbf{s},\mathbf{t}} = \cos^{-1}\left(\frac{\|\mathbf{s}\|^2 + \|\mathbf{t}\|^2 - \|\mathbf{s}-\mathbf{t}\|^2}{2\|\mathbf{s}\|\cdot\|\mathbf{t}\|}\right),$$

we continue as

$$Cov[Y(\mathbf{s}), Y(\mathbf{t})] = \left(\frac{\|\mathbf{s}\|^H \|\mathbf{t}\|^H}{2}\right)\left(\phi_{\mathbf{s},\mathbf{t}}^H + \frac{1}{\phi_{\mathbf{s},\mathbf{t}}^H} - \left(\frac{\|\mathbf{s}\|}{\|\mathbf{t}\|} + \frac{\|\mathbf{t}\|}{\|\mathbf{s}\|} - 2\cos\theta_{\mathbf{s},\mathbf{t}}\right)^H\right)$$

$$= \|\mathbf{s}\|^H \|\mathbf{t}\|^H \left(\frac{1}{2}\right)\left(\phi_{\mathbf{s},\mathbf{t}}^H + \frac{1}{\phi_{\mathbf{s},\mathbf{t}}^H} - \left(\phi_{\mathbf{s},\mathbf{t}} + \frac{1}{\phi_{\mathbf{s},\mathbf{t}}} - 2\cos\theta_{\mathbf{s},\mathbf{t}}\right)^H\right),$$

for all $\mathbf{s},\mathbf{t} \in \Re_{\mathbf{0}}^2$ and $H \in (0,1)$. Thus taking

$$R(\theta_{\mathbf{s},\mathbf{t}}, \phi_{\mathbf{s},\mathbf{t}}) = \tfrac{1}{2}\left(\phi_{\mathbf{s},\mathbf{t}}^H + \phi_{\mathbf{s},\mathbf{t}}^{-H} - \left(\phi_{\mathbf{s},\mathbf{t}} + \phi_{\mathbf{s},\mathbf{t}}^{-1} - 2\cos\theta_{\mathbf{s},\mathbf{t}}\right)^H\right)$$

we obtain from (2.1) the covariance function of $\mathbf{X}$ as

$$Cov[X(\mathbf{s}), X(\mathbf{t})] = Cov\left[\|\mathbf{s}\|^{-H} Y(\mathbf{s}), \|\mathbf{t}\|^{-H} Y(\mathbf{t})\right]$$

$$= \|\mathbf{s}\|^{-H} \|\mathbf{t}\|^{-H} Cov[Y(\mathbf{s}), Y(\mathbf{t})]$$

$$= R(\theta_{\mathbf{s},\mathbf{t}}, \phi_{\mathbf{s},\mathbf{t}})$$

for all $\mathbf{s},\mathbf{t} \in \Re_{\mathbf{0}}^2$. Hence from (1.2), we conclude that $\mathbf{X}$ is a RSRI random field, thereby proving the proposition.

3. Conclusions and Recommendations

In equation (2.1) from the proposition above, the first factor $\|\mathbf{s}\|^H$ is deterministic. This nonrandom term can be interpreted as the trend component of the LFBM $\mathbf{Y}$, representing its large-scale variation. The second factor, on the other hand, namely the RSRI random field $\mathbf{X}$, can be thought of as the random component of $\mathbf{Y}$, which represents the variation of the LFBM in the small scale.

With respect to stochastic characteristics, it is then clear that studying such characteristics of $\mathbf{X}$ is tantamount to doing the same for $\mathbf{Y}$. This means that the properties of the LFBM could be arrived at by first deriving the properties of the associated RSRI random field. For example, one could arrive at the spectral representation of the LFBM by using that of the RSRI random field – a property that is found in Tejada (2008).

This paper focuses on a characterization of the LFBM which is a member of the class of self-similar random fields. The result given here may be generalized so as to cover the said class. If such extension is made, a correspondence between self-similar random fields and RSRI random fields can be used in investigating the former with the latter as its "generating" random fields. Such approach is demonstrated in the one-dimensional case by Yazici et al. (1997), where properties of scale-invariant random processes on the line are used to characterize self-similar random processes.

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Teaching Experiments for a Course in Introductory Statistics

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College students' appreciation of the statistical science relies, to a large extent, on how the introductory course is managed. Two groups of students (undergraduate statistics majors and nonstatistics majors) were exposed to teaching an introductory course. Within each group, half is exposed to fun games intended as enrichment activities, while the other half served as the control. Grades after one semester were analyzed and treatment effect is computed through Heckman's Selection Model. While the treatment (games) is beneficial for nonstatistics majors, it is disadvantageous for statistics majors. For students with inherent interest in statistics, the introductory course will only require a clear presentation of concepts that will help them appreciate the discipline. However, the nonstatistics majors or those with negative perception on statistics, enrichment activities can help conceal their dislike for statistical science and help improve the eventual outcomes in the course.

Keywords: fun games, Heckmans' Selection Model, treatment effect

1. Introduction

Appreciation of people in the workplace or society in general on the statistical science can be traced back on how they were introduced to the discipline. Those who were not been convinced that statistics is important will remain to have the same perceptions even after they finished university work. It is a big challenge for teachers of introductory statistics course on how to introduce the course to attract the students' attention that will hopefully be translated into cognition and subsequently appreciation of the discipline.

Students may develop interest in any academic discipline depending on how pleasant their experience was the first time they were exposed to that area. It is postulated that Statistics can be better introduced to college students in a more casual and fun setting like in an ‘ordinary game.’ Thus, an experiment was done where one group receives—aside from the usual instruction—intervention (enrichment activities), while the other group has only plain classroom instruction. This paper aims to compare the performance of students with and without interventions, and to identify possible factors contributing to the outcomes in introductory statistics course.

2. Methods

An experiment is conducted to enhance student learning. Two sections of introductory statistics course for statistics majors and another two sections of introductory statistics course for nonstatistics majors from the University of the Philippines Diliman were identified to participate in the study. Each group were subgrouped further into control where instructions for one semester was undertaken using the usual classroom instructions. The other subgroup received the intervention where in addition to classroom lectures, enrichment activities (e.g., quotations, games, jokes and quiz bees) are done before, during, and after the presentation of a concept or a method. The purpose of such activities is to make the topics fun and more interesting and for students’ easier internalization and appreciation of the subject matter.

Activities given before the new lesson are intended to elicit the students’ interest and to have them desire to crave for more on the topic to be discussed. On the other hand, the activities given after learning the lessons are intended to wrap up, to emphasize important concepts and to unwind the class session. All these activities are ways to make the classroom experience more interesting and pleasurable for the students. According to Leblanc (1998), good teaching is also about style. It may be in forms that are entertaining but not necessarily lacking substance.

A quotation may serve as stimulants of students’ interest prior to the discussion of a new lesson. A quotation relevant to the new lesson/topic initially sets the mood of the class. The teacher does not only give the quotation but explains its implications as well.

- As an introduction to the definition and uses of statistics, the teacher can use the quotation by Florence Nightingale: “Statistics is the most important science in the whole world; for upon it depends the practical application of every science and of every art; the one science essential to all political and social administration, all education, all organization based on experience, for it only gives results of our experience.” After explaining the quotation, the teacher defines what statistics is and follows it up with its varied applications and uses. This allows the students to realize the magnitude of its usability not only in their field but also in other fields.
- On data presentation using statistical charts, a good quotation is from an ancient Chinese proverb that states “One picture is worth ten thousand words.” This

explains that once we put data in a chart, we obtain many significant findings. Hence, it is comparable to a painting wherein we can make different interpretations. On the other hand, if the teacher does not want to sound very philosophical, he/she can cite the first line of the song *If* by Bread that says "If a picture paints a thousand words…," the meaning of which is analogous to what was discussed.

- For the discussion of the different summary statistics like measures of central tendency and measures of dispersion, another quotation worth mentioning is by H.G. Wells (1929) that says "The time may not be very remote when it will be understood that for complete initiation as an efficient citizen of one of the new great complex worldwide states that are now developing. It is as necessary to be able to compute, to think in averages, maxima and minima, as it is now to be able to read and to write." This may sound profound however, we let the students realize that being statistics literate is analogous to knowing how to read and write. Every individual equipped with statistical tools has an edge in life. Many data are available but not enough researchers to do the analysis. Only a few has the statistical capability. The teacher emphasizes the fact that there is power in understanding figures.

Games, on the other hand, are done in the form of entertainment. This activity enhances thinking, cooperation, and unity among students. When the teacher incorporates games in class, this creates excitement and enthusiasm on the subject matter. Thru games, students will have a better understanding of the new concepts they need to learn.

- On data organization, the game "Arrange Yourselves" is appropriate. The game can be played in two ways – by small groups, and by whole class participation. In playing with small groups, there should be at least 10 members in each group. Students arrange themselves using quantitative variables like age, weight, height, foot size, and waistline. Instructions should be specific whether they will arrange themselves from lowest to highest or from highest to lowest. For the last call, the whole class participates. The entire class needs to arrange themselves according to the variables asked. After the game, the teacher processes the activity by stating that the objectives are 1) to show different ways of arranging individuals and 2) to know the advantages and disadvantages of arranging individuals. Then, the teacher elicits insights from the students regarding what they learned from the game.

  After processing the activity, the teacher discusses the raw data and the array and relates it to the game. Emphasis is on the convenience of obtaining the lowest and highest observations and where the observations are concentrated in the array. The teacher recalls the last game played where there is no more grouping and all the students arranged themselves according to magnitude. Students cite difficulties encountered in the last game and stress is placed on sorting being cumbersome when the number of observations is large. This is now a good opportunity to introduce the frequency distribution as a better way of organizing data and its benefits.

- Another activity that can serve as an appetizer is the “Find the Word” game. This is helpful in introducing the different terms that students should be acquainted with. The topic “Inferential Statistics,” in particular, involve the use of so many terms students are unaware of. The game will allow them to be conscious of the different terms utilized in inferential statistics. The students need not understand the meaning/s of the words yet but rather to give them exposure.

To end a topic in statistics, the teacher gives integration activities (e.g., jokes, quiz crossword, trivia, and quiz bee) to summarize the lesson, to lighten up the class session, and to highlight essential points. Jokes reduces the seriousness of the atmosphere and creates a relaxed mood in the classroom. Kher et al. (1999) say that humor is often overlooked as a teaching tool and that laughter releases stress and tension for both the instructor and the students. The joke should be related to the topic to be discussed for better understanding and appreciation on the part of the students. Adding humor lightens a rather difficult subject matter.

A quiz bee is given as the final activity before the semester ends. The contest serves as a review of all lessons covered and as a preparation for the final examination. As an incentive, the teacher gives prizes to the top three students who will win the contest. This activity motivates and challenges the students to study harder, do further readings, and be competitive. In addition, this creates an atmosphere of fun and excitement.

3. The Data

There are 58 statistics majors and 55 nonstatistics majors involved in the experiment. Same set of variables for both groups were collected at the same time:

- examination scores (long exams and final exam),
- grade, sex, age, height in inches, weight,
- daily physical activity,
- daily stress level,
- average weekly allowance,
- average weekly expense,
- membership in an organization, location of residence (urban, rural),
- status of current residence (1 – lives with parents, 2 – lives with relatives, 3 – lives with friends, 4 – lives in a dormitory, 5 – lives alone, 6 – lives in a boarding house, 7 – lives with family members)
- family status (1 – both parents living together, 2 – separated, both parents alive, 3 – separated, but one parent deceased, 4 – both parent deceased, 5 – one parent deceased)
- highest educational attainment of father
- highest educational attainment of mother
- number of siblings

- course and number of semesters in the University (for nonstatistics majors),
- number of semesters in the current program (for nonstatistics majors),
- status of current program
- grade in algebra, geometry, trigonometry, college algebra
- with honors in high school
- type of high school (1 – private, 0 – public)
- study habits (1 – studies everyday, 2 – studies 4 to 6 times a week, 3 – studies 2 to 3 times a week, 4 – studies once a week, 5 – studies only when there is an exam, 6 – does not study)
- attitude with numerical courses (1 – very interested, 2 – interested, 3 – neither, 4 – uninterested, 5 – very uninterested)
- number of times taken Stat 101 (for Stat 101 students only),
- and overall impression of Stat 114 or Stat 101 (1 – very important, 2 – important, 3 – neither, 4 – unimportant, 5 – very unimportant).

4. Estimation of Treatment Effect

The experimental units are students from two sections of statistics majors (divided into control and experimental groups) and two sections of nonstatistics majors (also divided into control and experimental groups). The control and treatment groups were given the same examinations (multiple choice type) for all topics covered.

The author taught all four sections included in the study. However, self-selection bias is still inevitable in this experiment since students are free to choose their teacher by enlisting to their preferred section. Heckman (1979) noted that sample selection bias may arise in practice for two reasons. First, there may be self selection by the individuals or data units being investigated. Second, sample selection decisions by analysts or data processors operate in much the same fashion as self selection. When samples are not randomly assigned to their respective groups, biased estimates of treatment effects can lead to misleading information.

We used the Heckman's selection model, a two-step statistical approach, which offers a means of correcting for non-randomly selected samples. The model avoids the sample selection problem by estimating the model parameters by maximum likelihood. The model provides consistent, asymptotically efficient estimates for all parameters in the model.

Heckman's selection model is based on two latent dependent models:

$$Y_1^* = \beta' X + U_1 \qquad (1) \text{ (regression model)}$$

$$Y_2^* = \lambda' Z + U_2 \qquad (2) \text{ (selection model)}$$

where X and Z are vectors of regressors, the errors U_1 and U_2 are conditional on X and Z, jointly bivariate normally distributed with zero mean vector and variance matrix $\sum$ where the following holds $U_1 \sim N(0, \sigma^2)$, $U_2 \sim N(0,1)$ and $Corr(U_1, U_2) = \rho$.

5. Results and Discussion

The final grade of nonstatistics majors is significantly affected by their grades in college algebra ($p<0.000$), grades in high school trigonometry ($p<0.013$), whether they agree that numerical courses are important ($p<0.093$), and the treatment ($p<0.000$). The partial contribution of the treatment on final exam could increase the grade by 0.856 in the 9-point grading system (1 is highest, 3 is passing, 5 is failing).

Selection to participation in the intervention is significantly affected by the number of semesters they stayed in the university so far ($p<0.028$). Those in their junior or senior years do not need the intervention much as this is needed by the freshman and those in their sophomore years.

Counterfactual simulations show that had all the subjects went through the same intervention, the final grade in Stat 101 is 1.94 compared to 1.98 had they not went through the intervention. This means an estimated treatment effect (due to the intervention) is about 0.0351 (or and increase of 1.78%). This is statistically significant ($p<0.000$).

Final grade of statistics majors is significantly affected by grade in high school algebra ($p<0.034$) and the treatment ($p<0.001$). Grade in high school algebra is a good indicator of performance in introductory statistics for statistics majors taken upon entrance in the program. The partial contribution of the treatment on final grade however, can lower the grade by 0.5449 in the 9-point grading system. While the intervention is an advantageous activity for nonstatistics majors, it has adverse effect on statistics majors.

None of the identified determinants of selection as participants to the intervention can actually dichotomize who needed and who do not need the intervention among statistics majors.

Counterfactual simulations show that had all the subjects went through the same intervention, the final grade in introductory statistics is 1.85 compared to 1.81 had they not went through the intervention. The statistics majors are better off in an introductory statistics course not to participate in the intervention ($p<0.000$). It is recommended that similar interventions can be developed that are more suited to the cognitive level of statistics majors, or simply not to use the current activities as this is detrimental to student performance.

6. Conclusion

Students understand what they are learning if classroom lessons are presented/ discussed in a more fun and interesting ways. Although time consuming, various techniques (e.g., enrichment activities – quotations, games, jokes and quiz bees) may be used to get the students' enthusiam in appreciation of the subject matter.

The objectives of this study are twofold. First, the study compares the performance of students with and without interventions. Second, the study determines factors affecting the grade of students in introductory statistics. The study suggests that statistics majors do not need these enrichment activities to get their interest in studying statistics. However, non-statistics majors may need to have interventions to appreciate statistics, improve cognition, and subsequently better course outcomes.

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Teaching of Statistical Consulting in the Philippines

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Teaching in a developing country is generally challenging due to the inadequate infrastructures in the development of teaching materials and the facilities in the delivery of such. The teacher has to be creative enough in developing cost-effective teaching materials, and efficiently allocating the limited resources. Statistical consulting is generally taught using audio-visual infrastructure support. In the Philippines, it has to be taught through case studies, coaching and guided practice to complement the absence or inadequate audio-visual facilities. The methods are fairly adequate in imparting to the students the techniques and necessary skills in the practice of statistical consulting.

Keywords: statistical consulting, statistics education

1. Introduction

Statistical consulting is the interpersonal relationship between the consultant and the client. Communication is the key element in the consulting process. The mechanics in which statistical methods are used to resolve the problems of the clients requires efficient communication dynamics between the client and the consultant. On the client side, the goal is to convey the problem clearly to the consultant. The consultant on the other hand, should be able to verify with the client that indeed, result of statistical analysis will provide enough information towards resolution of the real-life problem being consulted.

Teaching in the Philippines has been extra challenging over the years. While the youth and children population has continually been increasing, government expenditures to education have not increased proportionally. The proportion of expenditure to education, culture and manpower development hovers around 19% to total expenditure in the past few years (2000 Phil. Stat. Yearbook). Relative, to GDP, expenditure to education dropped from 4.4% in 1997 to 3.79% in 1999. This along with other economic and social problems stimulates creativity of the teachers on how to utilize the resources optimally to educate the youth.

While advocacy on the correct use of statistical analysis in the Philippines is still pushed by various stakeholders, the inadequacy of practicing statisticians should also be addressed simultaneously. Both the public and private sectors started to realize the need for statistical consulting since the 80s, but there are only a few trained statistical consultants in the country. Experience is usually required for statisticians to get contract from those needing their services. This often ends up bringing in consultants from other countries. It is important to conduct training and statisticians be exposed to such activities to develop the track record needed.

2. The Consulting Scenario

The consulting clients in the Philippines may be grouped into three: other researchers, the private sector and the public sector. Other researchers include graduate students working on their thesis, medical practitioners working for a paper to be submitted for publication, or other academe-based researchers working within the framework of academic publishing. Most of the problems usually consulted by these clients would fall in the area of research design including sampling and data collection strategies, descriptive analysis, and significance testing (with or without covariates). Significance testing would include verification of a previous result/ theory, comparisons, and validation of innovative diagnostic over a gold standard through the computation of sensitivity and specificity indices. These problems are addressed in a thorough discussion between the consultant and the client regarding the problem, insistent probing on the part of the consultant is proven effective.

The problems consulted by the public sector usually revolve around the generation and analysis of official statistics and in impact assessment for various development interventions. The most commonly required approaches are sampling design, small area estimation, statistical modeling where the data usually posed some constraints, indexing methods, and other aggregation/summarization procedures. Techniques of modeling under complex survey data, variance estimation in complex designs, and nonparametric estimation would usually help.

The problems consulted by the private sector are imposing so much challenge to the statistical consultant. Survey data and data mining are similarly dominating the consulting practice in private sector. Survey data are used in feasibility studies, product testing, pre-product launching and generally in the construction of a marketing strategy. The availability of large usage databases, loyalty cards information, electronic transaction records, requires much techniques from data mining procedures. These are subsequently used in business intelligence and other strategic marketing planning and decision-making. Many approaches however, have to be tailor-fitted for the firm due to the varying design of the data architecture and the information they are searching for. The consultant's immersion with the client to understand all the processes involved in the firm is necessary. Solution is usually complex but results are generally fulfilling.

3. The Teachers

To teach statistical consulting, it is important that the teacher have extensive experience in the business. The teacher should have a hands-on experience in a variety of consulting problems to be able to share to the students various approaches used in resolving such. Most of the consulting contracts especially with the private sector impose confidentially clause, the teacher then who has intensive consulting experience will be able to mask the identity of the firm involved in the problem discussed.

Since strategies used in resolving various problems usually vary, a clear presentation of such can help future consultants think creatively along that line once they are working with similar consulting problems in the future. The teacher should be able to illustrate to the students how clients are handled and the process in which certain problems are resolved.

One bottleneck in the metamorphosis of classroom-trained statisticians to become consultants is in the operationalization of statistical theory. There is difficulty to recognize the reality behind normal distribution and how to deal with it when reality is different from it. How will the statistician fill-in the compromise between statistical theory and really. These are the issues that the teacher of statistical consulting has to deal with the students.

4. The Student

Since consulting is not instantly learned in the classroom, students need to work with actual, real consulting problems. There are three possibilities to work on along this line. First, is to encourage students to extract problems from their workplace. They can also be assigned in the consulting laboratory within the school. Or, agreement with private or public firms can be made for the students to be exposed in an actual consulting problem with the guidance of the teacher.

The students should be willing and open to learn the creative rudiments of the consulting business. They should be open to new ideas, criticisms, acknowledgement and rectification of errors if needed.

The appreciation of the operationalization of statistical theory may take sometime, things that can be considered in the timing of a statistical consulting program.

5. Curriculum Development

Statistical consulting has been part of the graduate curriculum (masteral level) in the University of the Philippines, School of Statistics. The program is a 1 unit, 2-semeter course to be taken by the students in their second year in the program.

The program usually starts with the teacher presenting some pointers on the conduct of statistical consulting. The role of communication is emphasized in the process. The classroom discussion follows an informal format, similar to a question and answer discussion. The teacher would cite some cases based on consulting experience to explain to the students how to execute certain steps in the consulting process.

Although the application of certain methods are presented as need arises, the students are encouraged to explore the literature for a more sustainable learning process, instead of merely feeding them with certain methods.

The students are also advised to read not on statistics alone but also on the subject matter so they will fully appreciate the problem.

Towards the middle of the first semester, the students are assigned clients from the consulting laboratory. Oftentimes, these clients are graduate students from other disciplines seeking assistance on their respective thesis or other researches. The students are asked to discuss with the client the research problems, present this in class, and give a collective advice as to how to approach the problem. Once the consulting problem is completed the students are also asked to present results in class to share the approaches and strategies to their classmates.

Statistical consulting is generally taught using audio-visual infrastructure support (McCulloch et.al. 1985). In the Philippines, it has to be taught through case studies, coaching and guided practice to complement the absence or inadequate audio-visual facilities.

6. Some Evaluation Results

The student evaluation for the course and the teacher yields good impression from the students. In a scale of 1 to 4 where 1 is highest, the average rating on students interest on the course as well as their satisfaction on the way course is handled average to 1.58. The students found that enrolment in the course indeed enriches their statistical knowledge from the different core courses taken regularly in the program. They attribute the effectiveness of the course to the teacher's mastery of various statistical applications, the experience from various consulting activities, and a favorable student-teacher interaction.

Some recommendations of the students include the regular discussion of special topics at least once a month, compilation of consulting problems at the end of the semester, and addition of more consulting clients to each student.

7. Conclusion

Teaching of statistical consulting requires experience on the part of the teacher of actual consulting work. The exposure has to be varied to be able to target a wider class of consulting problems that the students may encounter later on. The creative use of case studies and exposure to actual consulting problems shall help students appreciate statistical consulting and observe the rudiments of the practice so they can develop into responsible statistical consultants later on. The students should be encouraged to explore not just the statistics literature, but also need to understand some basic background about the area where statistics is being applied.

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Contents

Editorial

This issue of *The Philippine Statistician* includes a good representation of research activities in the Statistical Sciences here in the country. The paper of **G. Vargas** represents the interest in financial econometrics that has been stimulated by the series of financial crisis in the region and worldwide. **A. Nalica** exposes the simultaneous treatment of spatial and temporal dependencies in the understanding of growth in rice production in the Philippines. Some nonparametric approaches in decision-making are used by **C. Alfonte** in modeling the decision-making process of the tuberculosis diagnostic committee. **J. Almeda and J. Yabes** provided a profile on KAP of the Filipino households regarding avian influenza – an epidemic that once struck the region.

The emerging role of computing in the development of statistical theory (computational statistics) is illustrated in the paper of **J. Gatpatan** while **J. Tejada** contributed to the foundation of spatial statistics.

Papers were contributed by two statistics teachers. One proposes an approach to develop interests of students in an introductory statistics course. The other paper shares how statistical consulting practice is taught in the university setting in the Philippines.

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