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Production constraints and their causes in the cacao industry in West Sumatra: from the farmers' perspective

HASNAH SEFRIADI[1], RENATO VILLANO[1], EUAN FLEMING[2] and IAN PATRICK[3]

ABSTRACT

We use structural equation modelling to conduct a path analysis for cacao production in West Sumatra, Indonesia, quantifying the main constraints identified by farmers attempting to increase their incomes. Stakeholders in a workshop identified low yield of cacao trees and low quality of cacao beans as the two main production constraints, which are the focus of this study. Farm-level data from 100 smallholders were analysed to describe and estimate the dependencies between various factors and their relationship to farmers' income. Five variables – source of cacao seedlings, expenditure on pest and disease management, expenditure on fertilizer, frequency of pruning, and pest and disease attack – were hypothesized to influence the yield of cacao trees. Yet farmers considered only fertilizer expenditure to have the expected positive influence. They considered lack of capital to be a critical factor indirectly impeding fertilizing practices. Expectations that farmers would perceive that the quality of their cacao beans and their ability to bargain would affect the price they received proved incorrect.

KEYWORDS: cacao farming; path analysis; production constraints; West Sumatra

1. Introduction

This paper presents results of an empirical analysis to identify the factors perceived by farmers in West Sumatra to influence their production of cacao. The aim of the analysis is to assess the effects of these factors on the gross incomes of these farmers. The views of farmers, particularly on complex cause-and-effect relationships, are often difficult to elicit in workshops in which other stakeholders participate. To overcome this limitation, a path analysis framework was adopted to determine the main constraints facing farmers. A cause-and-effect model within this framework was drawn initially as a problem tree in workshops. The structural equations method was then used to assess cause-and-effect relationships among the variables in the model.

Cacao is one of the estate commodities that play an important role in export earnings and employment opportunities in Indonesia. It ranks fourth in value among Indonesian export commodities. Indonesia contributed 15 per cent to total world cacao output in 2009/2010 and continued to be the third largest cacao producer in the world in 2011/2012 (ICCO, 2012). Cacao farming is the main source of income for more than one million smallholder farmers who own 94 per cent of the total cacao area. Cacao is planted throughout Indonesia, with Sulawesi producing 66 per cent of the national cacao output. Even though the output share of West Sumatra is much less than Sulawesi, it had the highest annual growth rate among the top ten cacao areas in the period 2004–2009. The share of cacao area to total estate crops area in this province increased six-fold during this period. Cacao area is expected to increase further in West Sumatra due to continuing government support programs to develop cacao-coconut intercropping farming systems. Due to the industry's importance to the economy and the role of smallholders in it, there is the potential for the industry to play an important role in poverty alleviation.

Some analysts (e.g. ACDI/VOCA, 2005; Akiyama and Nishio, 1997; Badcock, Matlick and Baon, 2007) noted that Indonesia's cacao industry has a comparative advantage in producing cacao beans due to low real costs, high productive capacity, efficient infrastructure and an open marketing system. This comparative advantage, however, has been threatened by a number of problems in production and marketing. ACDI/VOCA (2005), Handayane (2007) and Sahara, Dahya and Syam (2005) found that cacao yields in Indonesia could not achieve their potential. Improper use of fertilizer was identified as a cause of low production, while pests and diseases were thought to contribute to problems of low production and low quality. Improper fermentation was identified as another cause of low quality of cacao beans based on research by ACDI/VOCA (2005) and Handayane (2007). Other shortcomings have been observed that are marketing problems facing Indonesian cacao farmers. They include

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[1] UNE Business School, University of New England, Armidale, NSW, 2351, Australia.
[2] Corresponding Author. UNE Business School, University of New England, Armidale, NSW, 2351, Australia. efleming@une.edu.au
[3] Institute for Rural Futures, University of New England, Armidale, NSW, 2351, Australia.

weak bargaining position, lack of access to financial support and receiving a less remunerative price for fermented cacao beans (Djajusman, 2007). In order to develop the cacao industry in West Sumatra, the study aims to identify the factors limiting development and establish priority areas for action.

Attempts by government agencies to develop the cacao industry have confronted complex issues. Although the industry should be viewed as a system that includes production, marketing and institutional aspects, the analysis and discussion in this paper is limited to production. We cover agronomic practices, post-harvest practices and access by farmers to resources.

Data collection is discussed in the next section, and is followed by an explanation of the use of path analysis in model estimation in the third section. Results are discussed in the fourth section and the paper ends with concluding remarks.

2. Data collection

The study was conducted in West Sumatra province for two reasons. First, West Sumatra is designated as the production centre for cacao in Western Indonesia. Second, cacao development in this province is mainly funded by the provincial and regency governments, indicating their strong interest in developing the cacao industry. Three municipalities are involved in this study–Pasaman, 50 Kota and Solok–which were selected based on their distance to the export point. Solok is located close to the major provincial city and market of Padang; Pasaman is remote from Padang; and 50 Kota is located between these two spatial extremes.

Participatory impact pathway analysis (PIPA) workshops were conducted in the three municipalities at the initial stage of the study, which involved cacao industry stakeholders. It is now widely accepted that all stakeholders should have a voice in formulating and implementing government agricultural projects and programs (see Devendra, 2007; Grimble and Wellard, 1997; OED ADB, 2004). PIPA, propounded by Douthwaite *et al.* (2007; 2008), offers a method to achieve this goal, which is 'a practical planning, and monitoring and evaluation approach developed for use with complex projects in the water and food sectors' (Douthwaite *et al.*, 2008, p. 1). It engages an action research process based on impact pathways and contains a set of detailed assumptions and hypotheses that lead to the development of a set of strategies for a project to achieve its goals. These pathways describe normative actions by individuals and organizations for change, and how such change might influence the livelihoods of people (Douthwaite *et al.*, 2008). A fundamental component of the approach is the formulation of a problem tree to identify constraints to development. A shortcoming of PIPA is its inability to quantify and prioritize relationships in the problem tree from a stakeholder perspective. The ability to do this will lead to a better understanding of the relative importance of the different constraints encountered along each 'branch of the tree' or pathway.

The PIPA workshop enabled the cause-and-effect model to be drawn in the form of a problem tree as the basis for path analysis. Participants in the PIPA workshop identified low yields and low quality of cacao beans as the main problems constraining farmers from increasing their incomes. These problems were confirmed through surveys conducted in the three municipalities. Data were collected by interviewing a random sample of 100 heads of farm households using a structured questionnaire from September 2009 to March 2011. The information was gathered in relation to the period from June 2009 to May 2010.

The surveys identified a number of factors that were influencing cacao yield and quality in the cacao industry in West Sumatra. The path analysis method was employed to incorporate these factors as constraints facing farmers in model estimation, which is discussed in the next section.

3. Application of path analysis to cacao production

Path analysis is a method to interpret and decompose correlations among variables in linear causal models (Burridge and Schwabe, 1977; Kingsolver and Schemske, 1991). It is considered to be complementary to the PIPA approach. While PIPA focuses on constructing a problem tree and the use of qualitative data, path modelling allows data to be analysed quantitatively based on the problem tree.

Path analysis is a specific structural equation modelling (SEM) approach that represents hypotheses about effect priority by involving observed variables (Kline, 2011; Wolfle, 1980). It is also known as causal modelling which is often drawn in the form of path diagrams with the advantage of a visual presentation of a complex argument (Biddle and Marlin, 1987; Li, 1975).

The construction of models used in path analysis is based on the algebraic manipulation of standardized unidirectional path coefficients in systems of variables (Wright, 1965). This method works by applying prior knowledge that is constructed in the form of a diagram with an assumption of linear relationships among variables (Iriondo, Albert and Escudero, 2003; Kingsolver and Schemske, 1991). Correlation coefficients and regression analysis are used to model more complex relationships among observed variables (Schumacker and Lomax, 2004), improving the rationale of conventional regression calculations (Duncan, 1966).

Causal models inspired the development of SEM (Biddle and Marlin, 1987) through its integration with a confirmatory factor model (Schumacker and Lomax, 2004). Grace (2006, p. 10) defined SEM as 'the use of two or more structural equations to model multivariate relationships'. Poon (2007) suggested SEM as an approach that can be used to verify substantive theories that is also applicable to estimate a model that involves various types of data. Many analysts have referred to SEM as a mathematical tool for drawing causal conclusions from a combination of observational data and theoretical assumptions (Pearl, 2011). Barrett (2007) referred to SEM as a modelling tool that fits models to data, making model testing an important requirement to determine the fit of a model to data when using SEM.

Schumacker and Lomax (2004) pointed out some advantages of SEM as a method to test complex phenomena. Greater recognition is given to the validity and reliability of observed scores from measurement instruments. It treats the measurement error and statistical analysis of data separately. It is also able to analyse multi-group and multi-level variables.

The issue of causality is an important arena of debate among analysts. Sobel (2008) argued that structural parameters should not be interpreted as effect. His argument was supported by Biddle and Marlin (1987) and Shipley (1999). Biddle and Marlin (1987 stated that the SEM technique provides only associational or temporal relations among variables. They asserted that it cannot provide sufficient evidence to show the causal relations that some users claim and consequently misinterpret the results. This is the reason why some analysts, as listed by Pearl (2011), try to avoid the term, causality, by referring to covariance structure, regression analysis or simultaneous equations. However, Pearl noted that causal effect can be estimated from data without bias when all causal factors are estimable. Grace (2006) noted some arguments against the causal interpretation of SEM but also argued that it can support the argument for causal interpretation if it is built on the complete body of available knowledge. Biddle and Marlin (1987) provided several criteria to judge the success of SEM to confirm a causal model. They consist of the amount of variance explained in intervening and dependent variables, the significance of path coefficients in a path diagram, the relative sizes of regression coefficients, capturing paths by intervening variables, the significance of measures of fit, the significance of covariance among disturbances, model comparisons and sample comparisons. Kelloway (1995) suggested that SEM can provide a causal inference if the temporal ordering of variables is demonstrated and all relevant causes have been incorporated. The application of statistical relationships to causal interpretation has frequented the social sciences literature since the 1960s and the ecological literature since the 1970s.

There are several applications of SEM in the social sciences. Pajares and Miller (1994) used path analysis to test the predictive and meditational role of self-efficacy beliefs in mathematical problem solving. They stated that path analysis is appropriate in an investigation when social cognitive theory and previous findings have strong theoretical and empirical support for the hypothesized relationships. Cziráky *et al.* (2006) considered the use of SEM as a stand-alone analytical method to be applicable for regional development assessment, but argued that the methodological approach is enriched when combining the application of SEM with non-parametric classification methods such as cluster analysis. Hunn and Heath (2011) used path analysis to assess the causal relationship between life circumstances and depression, and their sequential effects on employment and welfare use. Lee, Weaver and Hrostowski (2011) used it to construct a conceptual model of the effect of the work environment and psychological empowerment on worker outcomes in public child welfare. Arsyad and Kawamura (2009) used it to assess their poverty causal model of cocoa smallholders in Indonesia. Said and Sallatu (2004) used it to construct a structural causal model for poverty incidence. SEM was used by Christensen *et al.* (1999) to assess the effects of age on anxiety and depression, and to examine whether age has direct effects on self-reporting of individual symptoms.

The SEM approach has also been applied in other disciplines such as environmental science (Leduc *et al.*, 1992), tourism (Gursoy, Jurowski and Uysal, 2002) and agricultural research (Asghari-Zakaria, Fathi and Hasan-Panah, 2007; Dalkani, Darvishzadeh and Hassani, 2011; Das *et al.*, 2010; Gantayat and Pattnaik, 2010; Iriondo *et al.*, 2003).

Path analysis is used in this study for four reasons. First, as indicated above it is a method to explore cause-and-effect relationships among variables in a complex system if underlying theory establishes a sound basis to expect causal relationships to be present. Second, all variables in the model are observed variables, which is one of the characteristics of path modelling. Third, path analysis provides the decomposition of the effects of variables that enables us to assess the indirect effects of exogenous variables on endogenous variables that are transmitted through intervening variables. Fourth, correlations among the variables can be estimated simultaneously.

Model specification

Path analysis begins with an initial structural equation model that is formulated on prior information. At this stage, relationships are specified to decide which variables causally affect other variables. Variables involved in path analysis are called measured variables because they are directly measured representing the data; they are also called observed or manifest variables. The measured variables can be categorical, ordinal or continuous (Kline, 2011).

Independent, intervening and dependent variables are also used in path analysis. The relationship between a dependent variable and a set of determinant (independent and intervening) variables can be represented by the generalized univariate statistical formula (Grace, 2006):

$$y_i = \alpha_i + \mathrm{BX} + \varepsilon_i \tag{1}$$

where y_i refers to an observed dependent variable, α_i represents an intercept, **X** refers to a vector of determinant variables, **B** represents a corresponding vector of coefficients (βs) that empirically link y_i to the elements in **X**, and the ε_i represent random errors associated with the i^{th} dependent variable. Equation (1) can be classified as a structural equation (Grace, 2006).

The relationships among variables in SEM can be visualized with a diagram (Kline, 2011) in which observed variables are represented with squares or rectangles and latent variables are represented with circles or ellipses. A line with a single arrowhead, which relates one variable to another, represents the hypothesized directional effect. Covariance between independent variables is drawn as a curved line with two arrowheads.

The base model for cacao production in West Sumatra is derived from the problem tree generated in the PIPA workshop, illustrated in Figure 1. It captures the perceptions by workshop participants about the

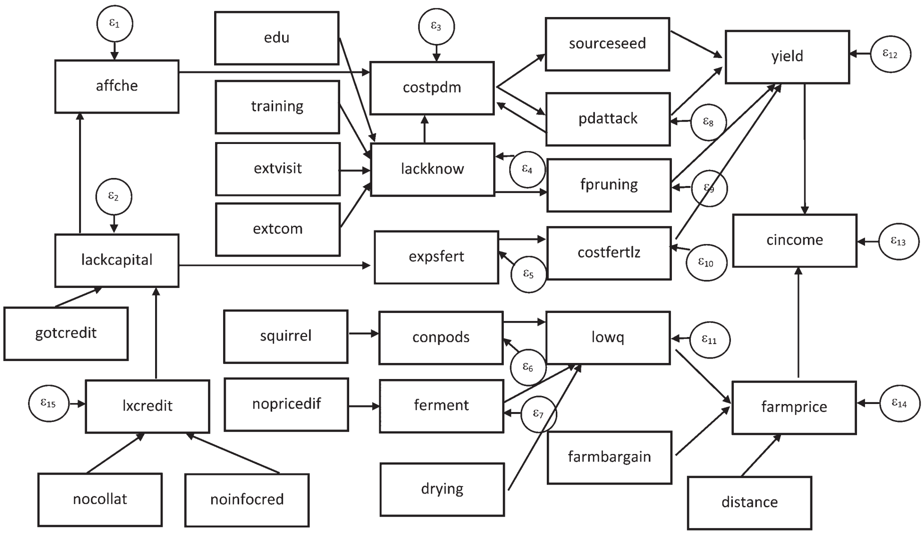

Figure 1: Base model for cacao production in West Sumatra

effects of changes in cacao production performance on the gross income of cacao farmers.

All variables in the model in Figure 1 are drawn with a rectangle because they are observed variables. Errors are drawn in circles because they are latent variables. The model is non-recursive because it has a direct feedback loop between variables *pdattack* (pest and disease attack on cacao trees) and *costpdm* (total cost of chemicals to control pest and disease). The reciprocal relation between these two variables is built on two assumptions. First, farmers may manage pest and disease for prevention purposes. Thus, pest and disease management activity can reduce pest and disease attack. Second, farmers may initiate pest and disease management when they face pest and disease attack. In this case, pest and disease attack influences pest and disease management activity.

Cacao income is at the end of the pathways in the model, measured as revenue from selling cacao beans. Even though the magnitude of the relationship between yield and farm income is known, the involvement of farm income in the model is for completeness to show the pathways from production performance to the economic condition of farmers.

Cacao income from the previous year may affect farmers' ability to obtain credit and thus be an indicator of lack of capital. This presumption allows us to connect *cincome* (cocoa gross income) to *gotcredit* (obtained credit in the past two years) and *lackcapital* (lack of capital) in the model. However, the correlation of those variables cannot be explored in this study due to the unavailability of data on cacao income in the previous year. In the model, the variable *nocollat* (lack of access to credit due to no collateral) is intended to capture a farmer's ability to obtain access to credit.

The variable in the model, *farmprice*, is the cacao price received by individual farmers. Tomek and Robinson (2003) stated that the price of a product is influenced by market structure, which is characterised by numbers of buyers and sellers, distribution size and the degree of product differentiation. The market structure for cacao beans in Indonesia is considered to be competitive because large numbers of farmers and buyers are involved in marketing without government intervention. The cacao value chain is characterised by individual transactions between sellers and buyers. At the farm level, individual transactions occur between farmers and two forms of marketing intermediaries: village buyers and wholesalers. Tomek and Robinson (2003) observed that unique attributes such as variation in quality of individual lots, different locations, differing terms of trade and imperfect information can generate price differentiation in individual transactions at any time. This issue is reflected in variable farm prices in this study to capture variations in individual farm-gate prices of cacao beans.

The system presented in Figure 1 can be written as 15 structural equations. Equations (2) to (6), equations (9) to (11) and equation (16) describe factors contributing to the yield of cacao beans. Equations (7), (8) and (12) formulate factors affecting the quality of cacao beans. Equations (13) to (15) relate to factors affecting the gross income of cacao farmers.

$$affche = \alpha_1 + \beta_1\, lackcapital + \varepsilon_1 \tag{2}$$

$$lackcapital = \alpha_2 - \beta_{21}\, lxcredit + \beta_{22}\, gotcredit + \varepsilon_2 \tag{3}$$

$$costpdm = \alpha_3 - \beta_{31}\, affche + \beta_{32}\, lackknow + \beta_{33}\, pdattack + \varepsilon_3 \tag{4}$$

$$lackknow = \alpha_4 - \beta_{41}\, edu + \beta_{42}\, training + \beta_{43}\, extvisit + \beta_{44}\, extcom + \varepsilon_4 \tag{5}$$

$$expsfert = \alpha_5 + \beta_5\, lackcapital + \varepsilon_5 \tag{6}$$

$$condpods = \alpha_6 + \beta_6\, squirrel + \varepsilon_6 \tag{7}$$

$$ferment = \alpha_7 + \beta_7\, nopricedif + \varepsilon_7 \tag{8}$$

$$pdattack = \alpha_8 + \beta_8\, costpdm + \varepsilon_8 \quad (9)$$

$$fpruning = \alpha_9 + \beta_9\, lackknow + \varepsilon_9 \quad (10)$$

$$costfertlz = \alpha_{10} + \beta_{10}\, expsfert + \varepsilon_{10} \quad (11)$$

$$lowq = \alpha_{11} + \beta_{111}\, condpods + \beta_{112}\, ferment + \beta_{113}\, drying + \varepsilon_{11} \quad (12)$$

$$yield = \alpha_{12} + \beta_{121}\, sourceseed + \beta_{122}\, costpdm + \beta_{123}\, pdattack + \beta_{124}\, fpruning + \beta_{125}\, costfertlz + \varepsilon_{12} \quad (13)$$

$$cincome = \alpha_{13} + \beta_{131}\, yield + \beta_{132}\, farmprice + \varepsilon_{13} \quad (14)$$

$$farmprice = \alpha_{14} - \beta_{141}\, lowq + \beta_{142}\, farmbargain + \beta_{143}\, distance + \varepsilon_{14} \quad (15)$$

$$lxcredit = \alpha_{15} - \beta_{151}\, nocollat + \beta_{152}\, noinfocrd + \varepsilon_{15} \quad (16)$$

where:

α_i refers to the intercept associated with the i^{th} dependent variable

i is the first subscript to identify the dependent variable in the equation, which has a value of 1, 2, 3, …

β_{ij} represents the path coefficient that links the i^{th} dependent variable and the j^{th} independent variable

j is the second subscript to identify the variable that has a direct effect on the dependent variable in the equation, which has a value of 1, 2, 3, …

The 26 measured variables consist of dependent, independent and intervening variables (Table 1). An independent variable in an equation can be a dependent variable in another. For example, *lackcapital* is a dependent variable in equation (3) while it is an independent variable in equation (6). Path analysis enables us to assess the effect of *lxcredit* (lack of access to credit) and *gotcredit* (obtained credit in the past two years) on *affche* (affordability to buy chemicals) that is transmitted through the variable *lackcapital* as an intervening variable in the model. The effect of all variables in the model on the income of cacao farmers, in turn, can be assessed simultaneously. This effect is discussed when interpreting the results. The next step in path analysis is to estimate the base model.

Estimation results

The path model of the cacao industry in West Sumatra was estimated using *Stata* Version 12 (StataCorp, 2011). The extent of multicollinearity in the model was measured using the variation inflation factor (VIF). A model is considered to have high multicollinearity when the value of VIF is greater than 10 (El-Dereny and Rashwan, 2011) or the correlation coefficient among the exogenous variables is greater than 0.9 (Grewal, Cote and Baumgartner, 2004). *Stata* results show that VIF values for all variables in the model are below 2, indicating that multicollinearity is not a problem in the model.

Before interpreting the results of the path analysis, the original model was assessed to determine whether it adequately fits the data. The goodness of fit of the model was tested using the root mean squared error of approximation (RMSEA), comparative fit index (CFI) and Tucker Lewis index (TLI). Many SEM analysts (e.g. Bayard and Jolly, 2007; Cai, Jun and Yang, 2010; Chi and Qu, 2008) have used these indices to assess model fit.

According to Kline (2011), RMSEA is scaled as a badness-of-fit index and follows the theory of a non-central chi-squared distribution. Its value is sensitive to degrees of freedom and sample size. The greater the degrees of freedom and the larger the sample size, the smaller the value of RMSEA is, where a zero value of RMSEA indicates the best fit and a value$\leq$0.05 indicates a good fit. To assess a model as having a good fit, the values have to be$\leq$0.05 for the lower bound (close-fit hypothesis) and$<$0.10 for the upper bound (poor-fit hypothesis). Streiner (2006) categorized values of RMSEA over 0.10 as a bad fit, values less than 0.08 as a reasonable fit, and values less than or equal to 0.05 as a good fit.

CFI is an incremental fit index that compares a model with a statistical baseline model (Kline, 2011). Its values range between 0 and 1, and a value$>$0.90 indicates a good fit of the model (Feldman and Bolino, 1999; Lester, 2009; StataCorp, 2011). Many analysts (e.g. Feldman and Bolino, 1999; Iriondo *et al*., 2003; Mulaik, 2009) noted that CFI is more reliable to assess the model fit for a small sample because it is not sensitive to sample size. TLI includes a correction for model complexity. A model is considered well-fitting if the TLI value is greater than 0.9 (Chi and Qu, 2008).

Values of fit statistics for the base model indicated that it was a poor fit according to the CFI (0.750), TLI (0.721) and the RMSEA test (0.096). To improve the goodness of fit, the model needed to be modified by removing insignificant variables and eliminating paths from the model (model trimming) or by building some more paths in the model (model building). Model trimming is done by constraining free paths to zero. Model building is done by specifying previous zero paths as free parameters. The aim of trimming and building models is to find a good model that fits the data, and can be justified on theoretical grounds Kline (2011).

Some of the estimated coefficients in the initial model were insignificant. There are two categories of insignificant variables: (1) those that do not have a significant relationship with all other variables; and (2) those that do not have a significant relationship with some variables while correlating significantly with other variables. The variables in the first category are *gotcredit*, *edu*, *extvisit*, e*xtcom*, *sourcesee*d, *cotspdm*, *pdattack*, *fpruning* and *farmbargain*. The variables in the second category consist of *affche*, *lackknow*, *lowq*, *condpods* and *ferment*. At the model modification stage, the variables in the first category were considered for removal from the model while those in the second category remained in the model.

In model trimming, six variables (*gotcredit*, *edu*, *extvisit*, e*xtcom*, *costpdm* and *fpruning*) in the first

Table 1: Description of variables in the path model of cacao production

Variable	Description	Unit
cincome	Farmer's gross income from cacao farming per hectare per year.	Rupiah
yield	Total quantity of cacao beans per hectare per year.	Kilogram
farmprice	Price of cacao beans received by farmers.	Rupiah/kg
sourceseed	Source of seedling farmers got for cacao farming.	2=from government program 1=other source
pdattack	Pest and disease attack on cacao trees.	2=yes; 1=no
fpruning	Frequency of pruning cacao trees per year.	2=yes; 1=no
costfertlz	Total cost of fertilizer per year.	2=yes; 1=no
expsfert	Reason for not fertilizing cacao trees.	2=expensive fertilize; 1=otherwise
costpdm	Total cost of chemicals to control pest and disease per year.	2=yes; 1=no
affche	Reason for not managing pest and disease.	2=cannot afford to buy chemicals; 1=otherwise
lackknow	Farmers are lack of knowledge on agronomic practices.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
edu	Years of educational attainment	years
training	Got training in the past 5 years	2=yes; 1=no
extvisit	Frequency of visits by extension officers per year.	Frequency of visits per year
extcom	Communicating with extension officer.	1=never; 2=sometimes; 3=often; 4=every visit
lackcapital	Farmers face lack of capital	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
gotcredit	Got credit in the past 2 years	2=yes; 1=no
lxcredit	Lack of access to credit	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
nocollat	Lack of access to credit due to no collateral.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
noinfocrd	Lack of access to credit due to not enough information on credit.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
lowq	The quality of cacao beans is low.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
condpods	Condition of pods harvested.	1=partially ripe; 2=mix of partially and fully ripe; 3=fully ripe
ferment	Number of days for fermenting cacao beans per activity.	Number of days
drying	Number of days for drying cacao beans per activity.	Number of days
squirrel	Reason for not harvesting fully ripe pods.	2=squirrel attack; 1=otherwise
nopricedif	Reason for not fermenting cacao beans.	2=no price difference; 1=otherwise
farmbargain	Ability of farmers to bargain on price of cacao beans.	1=no; 2=yes
distance	Distance of farmers' location to export point.	kilometre

category were removed. Removing *pdmanag* and *pruning* left variables *lackknow*, *training* and *affche* unconnected in the whole model; therefore, these three variables were also removed. Even though the effects of *sourceseed*, *pdattack* and *farmbargain* were not significant, they were remained in the model because the coefficients of *sourceseed* and *pdattack* have expected signs and removing *farmbargain* from the model contributed to worse model fit.

The resulting model had a better fit to the data than the base model with the CFI, TLI and RMSEA values of 0.910, 0.896 and 0.087, respectively. Even though the CFI value indicates a good fit, the other two fit tests indicate poor fit. Therefore, another round of modification was undertaken.

The second modification in building the model was conducted based on a modification indices test. StataCorp (2011) referred to modification indices as score tests (Lagrange multiplier tests) for the statistical significance of the omitted paths. They provide a suggestion for an additional path to improve the goodness of fit of a model. If a path with a high value of modification index is added to the model, it can generate a large improvement in overall fit (Kline, 2011, p. 217).

Many additional paths were suggested by the modification indices test to improve the model fit, but some did not make sense from a theoretical perspective. Therefore, only paths supported by theory were considered to be added in the model. Paths added to the model on the basis of the modification indices test were the paths from *distance* to *ferment* and *fertlz*, from *lackcapital* to *fertlz*, from *pdattack* to *condpods*, and from *farmbargain* to *condpods.* As the relationship between *expsfertl* and *costfertlz* was not significant, the variable *expsfertl* was removed from the model.

The second modification generated the final model, which is illustrated in Figure 2. The numbers near the arrows are path coefficients between the variables, while error values are located close to the error terms. Intercepts are written in the rectangles. Based on the model fit index test, it provides a satisfactory fit and is used for further analysis. The CFI, TLI and RMSEA values are 0.941, 0.928 and 0.070, respectively.

4. Interpretation of results

Model coefficients and their significance

For the purpose of comparing the predictive power of the predictor variables, the estimation result should be presented in the form of standardized coefficients. Kline (2011) noted that unstandardized regression coefficients cannot be used to compare the effect of predictor

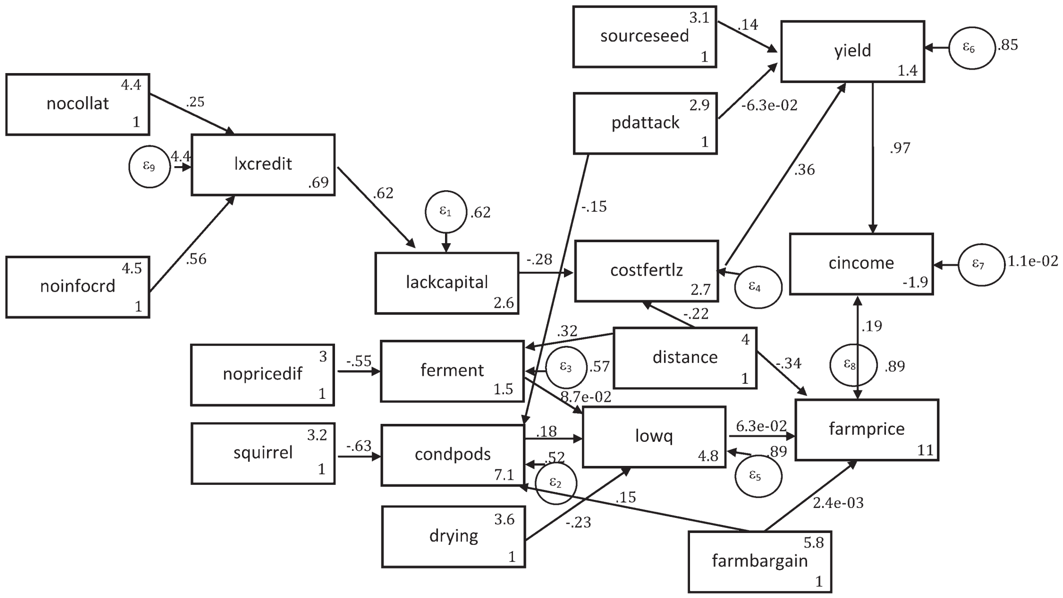

Figure 2: Final model for a path analysis of cacao production

variables in the model because they reflect the scales of their respective predictors with different raw score metrics. The standardized path coefficients of the causal model for cacao production are presented in Table 2.

Of all the path coefficients from the determinant variables to yield of cacao trees, only that from *costfertlz* (β=0.36, z=4.15) is significant at the 0.05 level, whereas *sourceseed* (the source of seedlings) and *pdattack* do not have significant effects. This figure indicates that the higher the farmers' spending on fertilizers the higher the yield of cacao trees.

Fertilizing practices play an important role in increasing the yield of cacao beans, yet about 31 per cent of sample farmers did not fertilize their cacao trees. Distance of farmers' location to export point and lack of capital are two factors significantly influencing farmers' fertilizing practices. Farmers located close to the export point (the capital city of West Sumatra) spent more on

Table 2: Maximum likelihood estimation of the final model

Endogenous variable	Exogenous variable	Standardized path coefficient	z-value
lackcapital	*lxcredit*	0.618*	10.31
	constant	2.597*	5.31
costfertlz	*lackcapital*	−0.282*	−2.99
	distance	−0.216*	−2.27
	constant	2.725*	5.64
condpods	*squirrel*	−0.628*	−11.84
	pdattack	−0.150*	−2.06
	farmbargain	0.148*	2.07
	constant	7.132*	11.86
ferment	*nopricedif*	−0.552*	−9.36
	distance	0.317*	4.48
	constant	1.499*	3.72
lowq	*ferment*	0.087	0.92
	condpods	0.181*	1.90
	drying	−0.229*	−2.47
	constant	4.791*	6.13
yield	*costfertlz*	0.362	4.15
	sourceseed	0.140	1.52
	pdattack	−0.063	−0.68
	constant	1.367*	3.29
farmprice	*Lowq*	0.063	0.67
	farmbargain	0.002	0.03
	distance	−0.338*	−3.93
	constant	11.140*	11.02
cincome	*farmprice*	0.189*	8.88
	yield	0.972*	169.35
	constant	−1.853*	−11.27
lxcredit	*nocollat*	0.248*	2.90
	noinfocrd	0.563*	7.32
	constant	0.692*	1.89

*significant at α=0.05 using a one-tail test.

fertilizers than remotely located farmers (β=−0.27, z=−3.15). This may relate to the survey result revealing that the price of inorganic fertilizer in remote locations was more expensive as a result of the higher cost to transport inorganic fertilizer to these locations.

In a previous study, Agbeniyi, Ogunlade and Oluyole (2010) found that economic constraint and unavailability of fertilizer were cited as the main reasons for not using fertilizers. 'Fertilizer is expensive', the main reason given for not fertilizing in this study, corresponds to the economic constraint reason observed by Agbeniyi *et al.* (2010), who suggested that the introduction of cacao pod husk fertilizer would be a solution to encourage farmers to fertilize their cacao trees.

In the workshop, farmers identified lack of capital as a constraint to the use of fertilizers. Model results reported in Table 2 reveal a significant negative relationship between these variables, with a standardized path coefficient of −0.282 (z=−2.99). This estimate implies that farmers who lack capital spend less on fertilizers.

Lack of access to credit was perceived by farmers to cause their lack of capital. The relationship between these variables was found to be significant and positive with a standardized path coefficient of 0.62 (z=10.31). Many studies (e.g. Ahluwalia, 1990; Bhutto and Bazmi, 2007; Coughlin, 2011; Debroy, 2004; Dorward *et al.*, 2004) confirm this result, finding that lack of access to credit is a major cause of lack of capital facing small farmers.

There are two factors affecting lack of access to credit (*lxcredit*) in the cacao industry: lack of collateral (*nocollat*) and lack of information on credit (*noinfocrd*). These two factors are significantly correlated to lack of access to credit with standardized path coefficients for *nocollat* and *noinfocrd* of 0.25 (z=2.90) and 0.56 (z=7.32), respectively.

About 17 per cent farmers got cacao seedlings from the government program. These farmers were expected to have higher yields than farmers buying seeds from other sources. However, model results reported in Table 2 show that the yield of cacao trees was not significantly higher for farmers who obtained cacao seedlings from the government program than for farmers who obtained their cacao seedlings from other sources. Most farmers (51 per cent) commented that good cacao seedlings were hard to get in their region. Furthermore, the prices of cacao seedlings were considered expensive by farmers and, therefore, they planted cheaper, low-quality seedlings (cited by 56 per cent of farmers). The price of a good seedling produced by PT Inang Sari (a certified cacao breeder located in West Sumatra) was Rupiah 3,500[4] at the time of the survey. To grow cacao trees on one hectare, farmers need to buy approximately 1000 seedlings, at a cost of Rupiah 3,500,000, while the price of a local cacao seedling at the time of the survey was Rupiah 2,000. This cost difference is the reason why farmers prefer to buy local seedlings.

Farmers did not consider infestations of pests and diseases in West Sumatra to have a significant effect on cacao production. It is a surprising result given that 41 per cent farmers reported that they faced this problem and 25 per cent of farmers claimed to have lost cacao output of more than 50 per cent. Further research is needed to examine this discrepancy between model and survey results.

Among the three variables presumed to affect cacao prices received by farmers, only distance was found to be significant with a standardized coefficient of −0.34 (z=−3.93). It means that the farther the location of farmers from the export point the lower the price they received. This figure implies a higher transportation cost for cacao beans located in more remote locations.

The low quality of cacao beans and bargaining position of farmers were hypothesized to have negative and positive relationships, respectively, with on-farm price in the original model. But these variables were found not to have significant relationships. This implies that farmers hold the view that the cacao price they receive is affected by factors that are not included in the model, most obviously by exogenous factors related to spatial price formation.

The issue identified in the workshop that low quality of cacao beans is a production problem in the cacao industry was confirmed by most respondents (61 per cent) in the survey. Model results reported in Table 2 show that, among the three possible causes, only *drying* (the number of drying days) (β=−0.23, z=−2.47) was thought by farmers to contribute significantly to the low quality of their cacao beans. The sign of the path coefficient from the *drying* to *lowq* (low quality of cacao beans) is negative, which is in line with expectations. The negative coefficient means that farmers expect a longer drying period to lead to a better quality of cacao beans.

The effect of the *condpods* (condition of pods harvested) on *lowq* does not have the expected sign. This result contradicts the theoretical perspective that when farmers harvest unripe pods it leads to a lower quality of bean. This issue needs further investigation.

The main reason for harvesting unripe pods proffered by 25 per cent of sampled farmers was squirrel attack. Results reported in Table 2 show a significant relationship between *squirrel* (squirrel attack) and *condpods* (β=−0.63, z=−11.84) with the expected negative sign on the path coefficient. It can be interpreted that the occurrence of squirrel attack discourages farmers from harvesting ripe pods. It means that attention should be paid to this issue; otherwise, it threatens the volume and quality of output of cacao beans.

An additional path suggested by modification indices from *pest and disease attack* to *condpods* results in a significant relationship between these variables (β=−0.15, z=−2.06). It indicates that pest and disease attack on their cacao trees worried farmers concerned with the spread of the infestation of pests and diseases to healthy pods that would cause greater losses. With pods subject to attacks by pests and diseases, farmers are tempted to harvest unripe pods as long as cacao beans coming from the unripe pods could be sold at the same price as ripe pods.

Building the model with an additional path from *farmbargain* to *condpods* improved the model fit. Farmers considered their ability to bargain on cacao price significantly affects the condition of pods they harvested (β=0.15, z=2.07). Those farmers who are able

[4] In early September 2013, 1,000 Indonesian Rupiah were approximately equivalent to £0.057, €0.067, and $US 0.088 (www.xe.com).

to bargain with buyers on cacao price tend to harvest riper pods. In this case, cacao beans from riper pods should be of better quality than those from unripe pods.

Fermentation practices are hypothesized to be positively correlated with the incentive of a price difference between proper fermentation and improper fermentation of cacao beans. Results reported in Table 2 prove that farmers identified a strong relationship between fermentation practices and the variable of no price difference (β=−0.55, z=−9.36). This estimate means that farmers will increase the period of fermentation if there is a price difference between appropriately and inappropriately fermented cacao beans. In other words, the proper fermentation technique would be adopted if there were a higher price received for appropriately fermented cacao beans.

Finally, results show that farmers located at a distance from the export point conducted fermentation for a longer period (β=0.32, z=4.48). This may relate to training conducted in remote locations where fermentation was the main piece of extension information obtained by farmers. Farmers expected that they could obtain a good price for their cacao beans if they fermented the properly. Unfortunately, this study reveals that better fermentation practices do not guarantee that farmers get a higher price.

Decomposition of effects of predictor variables on cacao income

Effects can be direct or indirect. Direct effect refers to the effect of one variable on another without involving intervening variables. An indirect effect is the effect of one variable on another that is transmitted through intervening variables. The sum of direct and indirect effects is defined as the total effect. Alwin and Hauser (1975, p. 39) noted that 'a total effect tells us how much change in a consequent variable is induced by a given shift in an antecedent variable, irrespective of the mechanisms by which the change may occur'. Indirect effects show how intervening variables influence the change in other variables, which in turn change the consequent variable.

The decomposition of the effect of predictor variables allows us to interpret the effects of each variable in the model. The standardized estimates of the effects of predictor variables in the model are presented in Table 3. Results suggest that support to increase the production of cacao trees and cacao market improvement are critical requirements to increase small farmers' income.

Among 17 factors in the model, seven factors are found to influence the gross income of cacao farmers. The indirect effects of predictor variables are transmitted through *yield* and *farmprice*. Of all the significant variables, yield has the strongest effect on cacao income (0.972). The second most important effect is cost of fertilizer (0.352), followed by farm price (0.187) and distance (0.139). While the total effects of cost of fertilizer and distance are constructed by indirect effects, the total effects of farm price and yield on farmers' gross income are due solely to a direct causal effect.

The effect of fertilizer use on farmers' gross income is mediated by yield. This total effect (0.352) can be computed by decomposing the indirect effects. To make the computation easy to follow, the direct effect of one variable on another needs to be shown. The direct effect of spending money on fertilizer on yield is 0.362 and the direct effect of yield on cacao income is 0.972. Based on these values the results indicate that, of the total effect of farmers spending money on fertilizer on farmers' gross income, 0.352 (=0.362 × 0.972) is directly transmitted by yield.

The effect of distance on cacao income involves three pathways. Along the first pathway, the effect is transmitted through farm price (−0.338 × 0.189= −0.064). The effect is mediated in the second pathway via the effect of cost of fertilizer on yield and its subsequent effect on farmers' gross income (−0.216 × 0.362 × 0.972=−0.076). Along the third pathway, the effect is transmitted via three subsequent variables: fermentation practices, low quality of cacao beans and farm price (0.317 × 0.087 × 0.063 × 0.189=0.0003).

Even though the total effect of lack of capital on cacao income is small, it has a strong effect on farmers' spending on fertilizer. Availability of capital at the farm level would increase cacao income through the effect of cost of fertilizer on yield and its subsequent effect on cacao income (−0.282 × 0.362 × 0.972=−0.099).

The effect of lack of access to credit in the model is an extension of lack of capital's effect on cacao income (0.618 × −0.099=−0.061). In a similar way, the effect of lack of information about credit in the model is extended via the effect of lack of access to credit (0.563 × −0.061=−0.034).

5. Discussion and conclusions

We presented results of an application of structural equation modelling in a path analysis framework to study farmers' views on causal relationships in cacao production. The application aims to identify the main production constraints faced by cacao farmers in West Sumatra. Two production issues analysed in this study were low yield of cacao trees and low quality of cacao beans. The analysis was conducted to identify factors influencing these issues by assessing the cause-and-effect relationships and to assess how these variables had an impact on farmers' gross income.

The yield of cacao trees had a direct effect on farmers' gross income while the effect of the quality of cacao beans was hypothesized to be transmitted through prices received by farmers. Of the five variables (source of cacao seedlings, cost of pest and diseases management, pest and disease attack, frequency of pruning and cost of fertilizer) presumed to be correlated to the yield of cacao trees, only the cost of fertilizer has a statistically significant effect that is in line with the expected direction of causation. This finding is consistent with the finding by Amusan *et al.* (2005) that minimal fertilizer use contributed to a decrease in the profitability of cacao farming.

Economic limitations were shown to discourage farmers from applying fertilizer. Lack of capital was found to be a critical factor that farmers thought indirectly affects their fertilizing practices. Lack of access to credit was perceived by farmers as a cause of lack of capital. Farmers believed that lack of collateral

Table 3: The effects of predictor variables in the model of cacao production

Endogenous variable	Exogenous variable	Standardized direct effect	Standardized indirect effect	Standardized total effect	z-value
cincome	*lackcapital*	-	−0.099	−0.099*	−2.90
	costfertlz	-	0.352	0.352*	3.89
	condpods	-	0.002	0.002	1.87
	ferment	-	0.001	0.001	0.91
	lowq	-	0.012	0.012	0.67
	yield	0.972	-	0.972*	88.61
	farmprice	0.187	-	0.187*	16.97
	lxcredit	-	−0.061	−0.061*	−7.86
	squirrel	-	−0.001	−0.001	−0.63
	nopricedif	-	−0.001	−0.001	−0.54
	drying	-	−0.002	−0.002	−0.64
	sourceseed	-	0.136	0.136	1.51
	pdattack	-	−0.062	−0.062	−0.68
	farmbargain	-	0.001	0.001	0.04
	nocollat	-	−0.015	−0.015	−1.75
	noinfocrd	-	−0.034	−0.034*	−2.10
	distance	-	−0.139	−0.139*	−3.21
yield	*lackcapital*	-	−0.102	−0.102*	−2.90
	costfertlz	0.362	-	0.362*	3.89
	lxcredit	-	−0.063	−0.063*	−7.86
	sourceseed	0.140	-	0.140	1.51
	pdattack	−0.063	-	−0.063	−0.68
	nocollat	-	−0.016	−0.016	−1.75
	noinfocrd	-	−0.035	−0.035*	−2.10
	distance	-	−0.078	−0.078	−1.93
farmprice	*condpods*	-	0.011	0.011	1.87
	ferment	-	0.006	0.006	0.91
	lowq	0.063	-	0.063	0.67
	squirrel	-	−0.007	−0.007	−0.63
	nopricedif	-	−0.003	−0.003	−0.54
	drying	-	−0.014	−0.014	−0.65
	pdattack	-	−0.002	−0.002	−0.60
	farmbargain	0.002	0.002	0.004	0.04
	distance	−0.338	−0.002	−0.337*	−3.58

*significant at α=0.05 using a two-tail test.

and lack of information on credit prevented them from getting credit.

The quality of cacao beans, the ability of farmers to bargain on the price of cacao beans and remoteness of farmers' location from export point were presumed to affect farm-gate price. However, the first two variables were found not to be significantly correlated to farm-gate price. This finding indicates that famers consider farm-gate price to be influenced by other factors not covered in the analysis.

Distance affects the production and marketing sides in the model. On the production side, it negatively affects farmers' willingness to apply fertilizer. The further the location from the export point, the lower the level of spending on fertilizer by farmers. This situation most likely relates to the price of fertilizer which is more expensive in more remote locations, making it less profitable to apply, but it was not explored in this study. Further research is needed to investigate fertilizer distribution.

On the marketing side, distance influences the cacao price at the farm gate. Farmers located farther from the export point received a lower price than those in close proximity. It does not seem that road condition is the cause because road infrastructure in the research location is in good condition. The difference in price by distance is assumed to relate to the marketing margin; however, this issue is not covered in this study.

In terms of the quality problem identified in the PIPA workshop, the quality of cacao beans is only measured based on dryness. Even though fermentation and condition of pods harvested theoretically affect the quality, these factors were not identified by farmers as significant. This suggests that no grading system exists in cacao marketing at the farm level. Evidence elsewhere indicates that such a grading system can have a positive impact on cacao quality and prices. For example, Anang *et al.* (2011) argued that the correct growing, drying and fermentation methods adopted by farmers contributed about 80 per cent to determine the quality of cacao beans. Farmers in Ghana allowed cocoa pods to mature properly before harvesting to ensure high-quality beans, according to Anang *et al.* (2011), and sorted out the good and bad beans to maintain the quality of cacao beans before selling them.

As well as confirming a number of expected causal relationships, the results yielded some unexpected findings. They provide support for further government intervention where existing conventional wisdom is substantiated, and for further research where it is not to determine whether the reason for the odd result lies with an exaggerated view of a problem in cacao production, a misguided perception of a problem by cacao farmers or a problem in model specification.

About the authors

Hasnah (hasnah@myune.edu.au) is a lecturer in the Faculty of Agriculture, Andalas University, Indonesia. She is currently a PhD candidate at the University of New England. Her research interests are in the areas of agricultural economics, community development and poverty alleviation.

Renato Villano (rvillan2@une.edu.au) is an economist and an associate professor in the UNE Business School. He specialises in applied econometrics, agricultural economics and development economics. His research areas include efficiency and productivity analysis in various sectors, agricultural marketing, poverty measurement and impact assessment.

Euan Fleming (efleming@une.edu.au) is an agricultural economist and professor in the UNE Business School. His main areas of research are agricultural economics, value chain analysis and development economics.

Ian Patrick (ipatrick@une.edu.au) is the director and senior research fellow of the Institute for Rural Futures at the University of New England. He is an agricultural economist with 20 years experience working in agricultural development. At present, he is working on improving producers (cattle and crop) smallholder access to developing urban markets in Cambodia and developing market incentives that improve smallholder poultry farm biosecurity in Indonesia.

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