Economic Development, Food Demand and the Consequences for Agricultural Resource Requirements (Indonesia)

Adam Briggs and Shyamal Chowdhury

University of Sydney, Faculty Agriculture and Environment

Selected paper prepared for presentation at the 58th AARES Annual Conference, Port Macquarie, New South Wales, 4-7 February 2014.

This paper has been independently reviewed and is published by the Australian Agricultural and Resource Economics Society on the AgEcon Search website at http://ageconsearch.umn.edu/, University of Minnesota, 1994 Buford Avenue, St Paul MN

Published 2014

Economic Development, Food Demand and the Consequences for Agricultural Resource Requirements (Indonesia)

Abstract: This paper analyses food demand patterns of Indonesian households from a resource intensity perspective, and quantifies the impact of changed demand patterns on the use of three major resource inputs - fossil fuel, land and water – in agricultural production. 13 major food items are categorised into low, moderate and high resource intensity, and income elasticity and Engel curves are estimated for the period from 1997 to 2007. Additional resource use due to changes in demand is quantified by controlling for real expenditure growth over the study period as well as consumption and budget share changes. The results show that income growth in Indonesia is associated with demand patterns that are more resource intensive. Per capita requirements of fossil fuel, land and water increased by 3.13(MJ), 1.24(m^2) and 2.1(KL) respectively relative to 1997 unit consumption levels. This study shows that at least for Indonesia, economic development will enhance challenges surrounding resource management, given the increased pressure on natural resource use resulting from food demand. The approach provides a useful foundation for further study into other developing countries similar to Indonesia in affirming connections between economic development and food demand that is more resource intensive.

Key Words: demand analysis, economic development, natural resource management

1. Introduction

Food demand is a core element of household behaviour strongly affected by economic development. The income growth associated with this phenomenon relaxes budget constraints, enabling households to purchase a wider range of food items that would otherwise be unattainable. Economic development underpinned by income growth drives changing food consumption patterns, reflective of emerging tastes and preferences for a variety of different foods. The literature has documented the changing nature of food demand in developing countries (for example, Blandford 1984; Herrmann and Röder 1995; Rae 1997), characterised by increased consumption of meat and processed goods at the expense of traditional staple items. Diverse empirical findings suggest that a convergence towards affluent 'westernized' consumption patterns on account of economic development is being experienced across developing countries (Regmi et. al 2008; Popkin 2006).Traditional analysis of dietary food demand, while interesting in its own right overlooks wider implications that can emancipate from food demand. This paper extends traditional analysis to consider the impacts of changing food demand patterns in developing countries upon resource use.

Establishing the nature of demand patterns from a resource use-perspective motivates this research given agriculture's significant use of major global resources. Approximately 50% of land (Smith et. al 2007), 70% of water (FAO 2002) and 3% of fossil fuel consumption, encompassing 10-12% of greenhouse gas emissions (Woods et. al 2010; Smith et. al 2007), are used globally for agricultural production activities. The premise that food demand can impact upon resource use is founded on Pimentel and Pimentel's (1979) research in quantifying the disparities in resource input requirements across food items. This is supported by Gerbens-Leenes et. al (2010) who argue that the largest change in food consumption patterns, significantly contributing towards natural resource use, concern developing countries. The specific aims of this study are to quantify impacts of food demand in terms of natural resource use. The research questions arising from this agenda seek to answer (i) the nature of demand for food as organised by low, moderate and high resource intensive categories; and (ii) the net difference in the per-capita level of resource inputs (fossil fuel, land, water) required to satisfy a unit of an average food consumption basket on account of demand changes over time.

The current research is directed towards the developing economy of Indonesia. Strong GDP growth per capita averaging 3.7% during the years 1970-2011 has driven momentous change throughout Indonesia's economy (Tambunan 2006; UNSD 2013). Indonesia has experienced rapid rural-urban migration rates of approximately 4.2% per annum since 1995 with over 50% of all Indonesians now living in urban centres as opposed to 35% in 1995 (UNDESA 2012). Literacy rates have improved from 75.3% in 1990 to 86.8% in 2007 (UNSD 2013). Improved educational outcomes have raised the opportunity cost of women's time, depressing fertility rates from 4.78 in 1973 to 2.59 in 2007 supporting female labour force participation and overall per-capita income growth (UNDESA 2013). These factors have increased the shadow value of home production and the preference for leisure, which in turn affect household food preferences away from traditional staple food items.

Significant changes in household demand have insinuated a strong response in the supply side of food, illustrated through the 'supermarket revolution' in Indonesia. Supermarkets supply a range of processed convenience goods which align with the preferences of households towards items which can be readily prepared on account of the higher value of leisure. This is especially driven by growth in female labour force participation which limits the time which can be allocated towards preparing traditional food items (Toiba et. al 2012 and Reardon et. al 2012). The implications of economic development on food demand patterns within Indonesia have subsequently received strong attention in the literature.

Studies by Kakwani (1977), Timmer and Alderman (1979) and Dixon (1982) pioneered the estimation of changing Indonesian food demand, showing that demand for staples (cereals, cassava, vegetables) are inelastic across households, in comparison to elastic expenditure behaviour towards meat, milk and eggs[1]. Pangaribowo and Tsegai (2011) estimated food demand across a range of demographic characteristics, reflective of economic development. This study demonstrated stronger demand for meats and processed goods to be associated with households displaying greater attainment of development outcomes.

It is clear that economic development has initiated a fundamental shift in the nature of food demand within Indonesian households in recent times. The history of Indonesia's development therefore provides an ideal case to consider whether economic development can be associated with food demand patterns that are more resource intensive. The long run nature of the Indonesian Family Life Survey data

[1] See also Deaton (1990), Jenesen and Manrique (1998), Fabiosa et. al (2005) and Widodo (2006) for further research.

used in this research spanning 10 years is also sufficient to estimate the net change in resource use which can be linked to food demand changes. The forthcoming results provide the first country-specific study linking economic development, food demand and agricultural resource requirements, raising a complex set of consequences in a world of increased resource scarcity.

This paper proceeds as follows: Section 2 explores the theoretical foundations of food demand patterns. An overview of Engel curve estimation and income elasticity of demand modelling is provided as the framework for demand analysis. Section 3 outlines the methodology applied in answering the research questions. Here, a description of the data, techniques in categorising food by resource intensity, demand analysis techniques and estimation of the additional amount resource use resulting from changed demand is outlined. Section 4 reports results for the estimated Engel curves and income elasticity of demand measures in illustrating demand behaviour from the perspective of resource use. The consequences for resource use across three key agricultural inputs are then estimated by comparing net changes in resource use attributable to changes in demand. This section will also provide a discussion of important implications that arise from the estimated results as well as recognising limitations inherent to the study. Section 5 concludes the paper where key consequences and areas for future research are identified and discussed.

2. Theoretical Model/Economic Framework

The objective of any household, underpinned by consumer demand theory is to maximise utility subject to a budget constraint. Following this, household food demand is modelled upon underlying tastes and preferences, which are in turn determined through a variety of demographic factors, both economic and non-economic. Household size, location and educational attainment, together with income and price changes are core factors which affect tastes and preferences and therefore food demand. Recognising the effect of household characteristics is therefore essential in estimating any model of economic demand. In this paper, household demand behaviour is modelled on the traditional demand frameworks of Engel curves and income elasticity estimation. This section focuses on the theoretical foundations of the Engel curve and demand elasticity concepts in how they support analysis of household demand for food. A discussion relating why economic development in theory is associated with higher resource intensive food demand is also provided.

2.1. Engel Curves

Engel curves (Engel 1857) describe how expenditure for a given commodity changes with household income. ‘Total expenditure’ has since emerged as a popular predictor variable since Engel’s contribution, on account of being more robust than an income measure (Engel and Kneip 1996). The curves have supported a range of empirical relationships concerning demand analysis, particularly Engel’s law which states that for a rising household income, the budget share allocated towards food will fall. Engel curves are useful in classifying any commodity as being a luxury, necessary or inferior good. The Engel curve provides useful insight into how household expenditure decisions compare across commodities, or between a subset of commodities as income (expenditure) changes.

Conventional estimation of Engel curves is based on a parametric model. This approach originated through the contributions of Working (1943) and Leser (1963), modelled as

$$Y_1 = \alpha_1 + Y_2\beta_1 + X'\beta_2 + \varepsilon_1 \tag{1}$$

where Y_1 is the food budget share of the household, Y_2 is the log household total expenditure, X' is a vector of observed household demographics, and ε_1 is the unobservable error assumed to satisfy $E(\varepsilon_1|Y_2)=0$.

The accurate estimation of the parametric approach therefore depends upon the specification of a functional form that reflects the underlying distribution of the data. A range of double-log, semi-log and other functional forms (see Howe et. al 1979; Deaton 1985 and Kneip 1994, for example) have developed from the need to capture diverse commodity expenditure patterns. As economic theory fails to detail a 'correct' parametric model, on account of unobservable and/or unverifiable distributions, non-parametric approaches to estimating Engel curves have received significant attention in the literature (Engel and Kneip 1996). The non-parametric approach removes the specification of an underlying functional form, which relaxes the requirement of conditional expectation on commodity expenditure (the dependant variable) for a given income/expenditure level. While non-parametric approaches offer theoretical advantages concerning Engel flexibility, parametric Engel curves more than satisfy the objectives of this paper concerning demand estimation. In recognising the merits of non-parametric specification, it is unlikely that any additional gain will be made towards establishing the nature of demand patterns here compared to the parametric approach.

The estimation of Engel curves is not exempt from the issue of endogeneity. As total expenditure is often determined by expenditure shares of commodities themselves, this variable will commonly be endogenous to the model (Blundell et. al 1998). Failing to control for any endogeneity will break down an accurate estimation of the structural Engel curve relationship. Furthermore, total expenditures may be mismeasured from expenditure surveys given the infrequent purchase of particular commodities (Meghir and Robin 1992). This notion is applicable to food, given that differences in the perishable nature of food items impact upon the size and frequency of item purchase. These issues show that any estimation, parametric or otherwise, of Engel curves should account for endogeneity and mismeasurement of household expenditure to preserve the integrity of estimated curvatures.

Lebwel's (2012) method is a novel technique to address these estimation issues. This approach overcomes the problem of mismeasured and endogenous regressors through a heteroskedastic covariance restriction, used to construct internal instrumental variables (Mishra and Smyth 2012). This scheme is useful as it relaxes the requirement that the standard exclusion restrictions be met in order to attain effective instruments. Lewbel's approach is used in this paper, providing a flexible alternative when controlling for mismeasurement and endogeneity during Engel curve estimation.

2.2. Income elasticity of demand

Complimenting the correct specification and estimation of Engel curves, the income elasticity of demand demonstrates, for a particular change in income, the amount of marginal income allocated towards a particular commodity. Formally the income elasticity of demand is described as

$$\eta_{ij} = \frac{\partial F_i}{\partial Y_j} \times \frac{Y_j}{F_i} \tag{2}$$

where η_{ij} = elasticity of income of item *i* for household *j*; F_i = food item *i*; Y_j = income of household *j*.

The income elasticity is important when assessing how a household will respond to a change in income, when considered across a range of household income levels. Controlling for core household demographics facilitates insights into the effect that development has upon food demand patterns in the way households allocate additional income across food categories. This is empirically measured through specifying a simple log-log regression function where all OLS assumptions are applied:

$$\ln Q_{ij} = \alpha + \beta \ln M_j + \gamma \boldsymbol{X} + \varepsilon_{ij} \tag{3}$$

where Q_{ij}= Quantity of food *i* consumed in household *j*; M_j= income level in household *j*; $\boldsymbol{X}$ is a vector of core household demographics.

When interpreting this model a 1% change in income will be associated with a $\beta\%$ change in quantity of food consumed, consistent with the income elasticity of demand definition. Introducing household demographics into the model will capture the effect of non-economic variables on household food demand patterns.

2.3. Demand for resource intensive food items

The theoretical objective that underpins consumption is the maximisation of utility subject to a budget constraint. Any value difference between two comparable goods should be attributable to the level of inputs embodied into the goods. The production of consumer goods is supported by a variety of inputs which ensure that the good will align with consumer preference in seeking utility maximisation. Therefore the value of the good can be somewhat justified by the input levels supporting production. Such 'high value' goods are preferred to those with fewer inputs, on account of better achieving utility maximisation, reflected through a higher willingness to pay.

A similar analogy is drawn when food is considered to be the consumptive item of choice. Food items that require a greater amount of resource input are typically more expensive on account of the higher opportunity cost of production to those with fewer resource requirements. On account of seeking utility maximisation, only households with relatively high disposable incomes are able to consume higher value food items. This paper proceeds on the premise that higher resource intensive items will experience greater demand by richer households. Arguably, these goods contain a greater capacity to satisfy utility, consistent with evolving tastes and preferences of households influenced by economic development.

3. Methodology

3.1. Data

This paper uses the Indonesian Family Life Survey (IFLS) data, a longitudinal survey that collects a variety of socioeconomic and health indicators at the household and community level. So far four survey rounds have been conducted in years 1993, 1997, 2000 and 2007 (Strauss et. al 2009). The IFLS has attempted to recontact all original households to encourage intertemporal household behaviour analysis. Recontact rates have been maintained above 90% in all rounds, an outcome promoting the power of this survey data in household analysis (Strauss et. al 2009). The IFLS sample represents 83% of the Indonesian population considering 13 of 28 provinces. As the earliest IFLS round of expenditure methodologies are inconsistent with later techniques, IFLS1 (1993) has been omitted from the analysis. Nonetheless, insights into long-run household behaviour are still possible through considering three rounds for 1997, 2000 and 2007.

The data covers a rich array of demographic variables recorded at household and community levels, with the most relevant aspect of the survey relating to household food expenditure and consumption. The IFLS records expenditure information (recall period of one week) for 38 individual food items. However consumption recorded in quantity terms is absent from the dataset. This is an essential component in modelling food demand behaviour. Deaton and Zaidi (2002) argue that when quantity data is absent from consumption information, price data from the relevant community is the next preferable alternative for calculating consumption quantity amounts. Fortunately the IFLS records food price information at the community level[2]. Items for which food prices are available at the community are not entirely consistent with the items recorded at the household level, with just 13 food items matching with those considered at the household level. These 13 items account for approximately 70% of total food expenditure across the 38 items, indicating that a meaningful analysis can still be conducted, despite restrictions in the scope of food items available for consideration. To ensure that all food consumption quantity is calculated in consistent units, prices are converted to either kilograms or litres where appropriate. In the case of missing prices at the community level, the average price at the province is used as a replacement proxy for the missing price. Consumption, expenditure and other demographic variables measured in time units have been converted to annual terms where necessary to ensure consistency. As households were surveyed over the entire year, any bias caused by seasonal availability of food can be controlled for when scaling up from weekly to yearly consumption behaviour given the staggered nature of the sampling timeframe (Strauss et. al 2009).

Aside from food expenditure and prices, a variety of other demographic variables have been utilised from the IFLS to control for various economic and noneconomic factors affecting food demand. A fundamental measure of household income is not provided with a single specification and has been constructed from a range of indirect measures for the purposes of this study. The variables used here

[2] Incorporating price information with expenditure amounts allows for the quantity consumed per household to be estimated.

consist of salary, farm business income, asset income outside business activity, non-labour earnings, self employment income and transfer income. These variables were scaled up to be measured in yearly terms where necessary. The exhaustive list of all variables extracted from IFLS for demand analysis is listed in appendix item I. The main variables used in the study are listed below in table 1.

Table 1 Key Variables

Variables	Units	Description
Income	Indonesian Rupiah (IDR)	Annual per capita household income constructed from salary, farm business income, asset income outside business activity, non-labour earnings, self employment income and transfer income
Price	IDR	Per unit price (kg or litres) for food item
Expenditure	IDR/capita	Annual per capita expenditure on food item/group
Consumption Quantity	(kg or litres)/capita	Calculated annual consumption quantity
Education of Household Head	1-9	Level of education attained by household head. 1=elementary 9=post-graduate
Household Size	Persons	Total persons in household
Average Household Age	Years	Average age of household
Marital Status	Dummy Variable	1 if household head is married, 0 if otherwise
Distance to nearest market	Km	If market is not located in community, how far to nearest?
Distance to nearest financial institution	Km	If financial institution is not located in community, how far to nearest?

3.2. Categorizing food by resource intensity

Analysing food demand patterns with respect to resource intensity requires the 13 food items be categorised with respect to resource input requirements in production. Three major agricultural resource inputs - fossil fuels, land and water – underpin the organisation of the resources into their respective categories. Table 2 displays the food items corresponding to categories of low, moderate and high resource production requirements.

Table 2 Resource Input Categories

Low	**Moderate**	**High**
Rice	Noodles, Rice Noodles, other chips	Beef, buffalo, goat
Cassava/Tapioca	Tofu/Tempe	Chicken, duck
Sago/Flour	Granulated Sugar	Fish, Oyster, Shrimp, Squid
Other Staples (potatoes, yams)	Milk (fresh, canned, condensed)	Cooking Oil
Green Vegetables	Salt	Bottled Water
Fruits	Salted Fish	

The organisation of the food items into the above categories is based upon the findings of agronomic research concerning levels of resource inputs for fossil fuels, land and water. Across all resource input categories, the average proportional changes are comparable between the resource intensive groups. Appendix item II reports the full details of the input requirements for individual food items. Table 3 shows the level of resource inputs across the three groups averaged for the 13 food items. The final column reports on the relative resource needs averaged across all inputs. The input scale indicates that food items in the moderate resource category require 1.4 times more resources relative to the low category, whereas the high category is 15.54 times more relatively resource intensive than the low.

Table 3 Food Resource Categories and Required Inputs[3]

Food Category	Fossil Fuel (MJ/kg)	Land (m^2/kg)	Water (KL/kg)	Average Relative Change ($\bar{\gamma}$)
Low	2.35	1.02	0.868	1
Moderate	8.08	1.51	1.98	1.4
High	26.73	12.6	22.494	15.54

Methodology which organises agricultural production by a comprehensive ‘resource intensive’ measure is scarce. The few sources of methodology which have been developed in the literature (Gerbens-Leens et. al 2002, Sainz et. al 2003) focus on estimating resource use in agriculture only from a fixed perspective, such as land use, and have complex data requirements in order to complete estimation. This highlights the shortfall of research methodology detailing comprehensive multi-dimensional frameworks which offer scope for calculating agricultural resource input requirements, as required by this paper. Nevertheless, this paper offers an introductory approach to the development of a resource intensive scale considering three resource inputs.

Recognising Indonesia’s trade patterns has important impacts upon the required resource input levels. The Indonesian government has pursued a policy agenda towards self-sufficiency in the production of agricultural commodities since the early 1970’s, driven by concerns over the adverse effects of exposure to price volatility on the welfare of domestic producers and consumers. However, FAO trade statistics and food balance sheet data reported in table 4 shows a growing trade deficit over the decade 1997-2007 when considering food items corresponding to the resource intensive categories. This comes in spite of growing domestic production. These trade figures shows Indonesia relies upon both domestic and international production sources in meeting food demand profiles, despite ambitions of self-sufficiency.

As production systems within Indonesia differ to foreign production systems in underlying characteristics and technology, inconsistent resource input requirements exist for equivalent food items (Pimentel and Pimentel 1979). Changing food demand patterns has seen a growth in Indonesia’s reliance on importing agricultural products from the US and other industrialised agricultural producers (Dyck et. al 2012). Therefore, resource requirements in an industrialised production setting have been

[3] See appendix item II for detailed food items individual resource input requirements. Fossil fuels are measured in mega joules (MJ) = 10^6 joules; land measured in square metres (m^2); water measured in kilolitres (KL) = 1000 litres.

Table 4 Value of Agricultural Trade (IDR '000)

Resource Category	Year	1997	2000	2007
Low	Export	1636.43	1510.61	2821.77
	Import	3583.62	3574.92	7236.24
	Domestic Production	22561.93	16321.47	37307.43
Moderate	Export	84.93	228.86	299.63
	Import	1526.64	2027.53	4467.51
	Domestic Production	2660.53	1987.03	3589.08
High	Export	2326.04	1696.07	8744.84[4]
	Import	5710.81	5907.04	13082.2
	Domestic Production	6268.26	3763.05	12336.4
Total	Export	4047.4	3435.5	11866.2
	Import	5710.8	5907	13082
	Domestic Production	31490.7	22071.6	53232.9

Source: FAO (2011)

incorporated in addition to domestic production resource requirements in recognition of Indonesia's trade profile. The resulting resource input figures reflect the average of the resource input requirements across both industrialised and domestic production contexts where appropriate. This inclusion captures the dynamics of Indonesia's food trade, where industrialised countries have continued to supplement Indonesian food stocks despite the self-sufficiency policy agenda.

The defined food categories, organised by resource input requirements, form the basis for the demand analysis and additional resource use estimation.

3.3. Engel Curve Estimation

Engel curves are estimated for food items organised by both dietary and resource intensive means. The analysis of food demand from a dietary perspective is necessary to establish whether the IFLS data used conforms to the broader literature which cites convergence in developing countries towards an affluent, westernised diet. Engel curves are used to establish the demand patterns from a dietary perspective. Upon establishing this empirical relationship, analysis concerning resource intensity proceeds on the basis of being underpinned by convergence towards affluent food consumption patterns from a dietary perspective, which dominate findings of the wider literature.

[4] The significant increase in value for the high resource intensive food export value can be accounted for exports in Palm Oil (controversial Indonesian agricultural activity). Over 90% of the rise in export value is attributable to this commodity alone. Omitting Palm Oil exports results in a trade value deficit for this category.

Lewbel's (2012) two-stage estimation approach is used to control for issues of mismeasurement and endogeneity of household expenditure. Lewbel's (2012) method is discussed for the estimation of food budget share Engel curves. The triangular system for the relevant Engel curves is presented as

$$Y_1 = \alpha_1 + Y_2\gamma_1 + X'\beta_1 + \varepsilon_1 \tag{4}$$

$$Y_2 = \alpha_2 + X'\beta_2 + \varepsilon_2 \tag{5}$$

where the Y_1 is food category budget share, Y_2 is the log real total expenditure and X' is a vector of exogenous regressors entering into the estimation.

Typically, Y_1 is estimated by identifying instruments for Y_2 that satisfy the standard exclusion restrictions[5] if $\beta_1 \neq 0$. Lewbel (2012) proposes that instrument identification can be achieved independent of the exclusion restrictions, provided that there is a set of exogenous variables Z (equivalent to X' in this estimation) with heteroskedastic errors in $(\varepsilon_1, \varepsilon_2)$. The set of variables compromising X' and equivalently Z are: natural logarithm of household income, household size, average age of household members, household location dummy (rural/urban) and maximum education level of household head.

In the first stage, the endogenous variable Y_2 is regressed on the Z vector defined above and the vector of residuals ξ are obtained

$$Y_2 = \alpha + Z'\gamma + \xi. \tag{6}$$

The estimated residuals are used to create instruments in estimating equation (4) through the form

$$X_j = \left(Z_j - \bar{Z}\right)'\xi \tag{7}$$

where Z_j is the estimated mean-centred residual for the given exogenous variable, $\bar{Z}$ is the centred mean of Z_j , ξ is the vector of errors and X_j is the estimated instrument.

Application of the Breusch-Pagan test of heteroskedasticity strongly rejects the null of homoskedasticity for the residuals, satisfying Lewbel's condition for heteroskedastic errors in the first stage estimation. The instruments generated from equations (6) and (7) are used to estimate Y_1 in the second stage. Hence identification for Y_1 is provided in the absence of the standard exclusion restriction assumptions for instrumental variables. Appropriate identification using Lewbel's (2012) method is sufficient for controlling for endogeneity and mismeasurement, reinforcing the integrity of the estimated coefficients. Work completed by Emran and Hou (2013), Baum et. al (2013) and Mishra and Smyth (2012) further demonstrate the value of the approach in providing robust identification in the absence of the standard exclusion restrictions.

Engel curves are estimated for the expenditure share relationship relating to the five food categories (staples, fruit/vegetables, dried food, animal products, condiments) and resource intensive categories

[5] The standard exclusion restrictions specify that identification for β_1 is provided when the variable Z_i is uncorrelated with the error terms and the correlation between the endogenous regressor and Z_i is different from zero.

(low, moderate, high) using the method outlined above. Initial estimation concerning food categories will establish whether household behaviour is consistent with wider empirical findings surrounding transitions to westernised food consumption. This provides the platform in extending the analysis of food demand towards a resource-use perspective provided that this caveat is satisfied. The estimated coefficients arising from this process are used to predict the share of the category's food expenditure across households, resulting in the estimated Engel curve.

3.4. Elasticity of Demand

The model used in estimating income elasticities for each resource intensive category, supplementing the Engel curve results, will be the log-log OLS regression model. Expressing the dependent variable and relevant independent variables in natural logarithm form will facilitate the interpretation of the estimated coefficient as an elasticity. The inclusion of a vector of demographic variables at the household and community level controls for important economic and non-economic factors that will impact upon the estimation of income effects on consumption. The model utilised in the analysis is presented as

$$\ln Q_{ijkty} = \alpha + \beta_1 \ln P_{ijkty} + \beta_2 \ln Y_{ijkty} + \beta X_{jt}[Demo] + \beta X_{ct}[Community] + \varepsilon_{ij} \qquad (8)$$

where *i*=1,2,…,12 (food item); *j*=1,2,…,*n* (household); *k*=1,2,3 (resource intensive food category); c=1,2…,321 (community); *t*= 1997,2000, 2007 (survey year); *y*=1,2,3,4 (income quartile).

Elasticities are estimated for each food item *i* within resource category *k*. Individual item elasticities are weighted by their expenditure share of the relevant category, before being aggregated in accordance to the definition of the category. Aggregating individual item weighted elasticities maintains accuracy compared to the aggregation across heterogeneous food items prior to estimating a grouped elasticity. Elasticities will be estimated with respect to income quartiles, by urban/rural locality and a pooled measure, to illustrate the differences in food demand profiles across a variety of Indonesian households.

3.5. Additional Resource Requirements

The estimation of additional resource needs attributable to changed food demand is a valuable contribution of this research and the final component in analysing economic development and resource use. While the concept of additionality is inherently challenging to establish in most applications, quantifying the net change in resource use attributable to demand changes provides a basis to illustrate the tangible impacts that economic development has for resource use. The estimates are based upon the resource scale outlined in section 3.2, which is assumed to remain constant throughout the study period[6]. Both 'absolute' and 'relative' changes to resource requirements are considered.

[6] Assuming constant resource input requirements over the study period can lead to both upward and downward bias in estimation. The former can occur from failing to recognise any improvements in technology and production efficiency which can potentially reduce input requirements. The latter can be attributable to increased scarcity in resource use which drives production to rely on increasingly marginal resources, impacting efficiency.

3.5.1. Absolute Requirements

Estimating absolute additional resource use is completed for the three resource inputs of fossil fuel energy, land and water. The four expressions in table 5 have been constructed to compare the amount of resources used to satisfy food demand through the study period:

Table 5 Key Terms in Quantifying Absolute Additional Resource Use

Term	Description	Interpretation
$Base_i = (q_{ir}c_{0i})$	Resource input (r/kg) required for the resource intensive category, weighted by share of total consumption in resource terms (1997)	Resource level required to satisfy given share of consumption in 1997
$D_{1ir} = (q_{ir}c_{1i})$	Resource input (r/kg) required for the resource intensive category, weighted by share of total consumption in resource terms (2007)	Resource level required to satisfy given share of consumption in 2007
$D_{2ir} = (Base_i Exp_{0i})$	Baseline resource use multiplied by real expenditure growth[7] from 1997-2007	Resource level required to satisfy a share of consumption in 1997 when taking into account real expenditure growth
$D_{3ir} = (Base_i Exp_{1i})$	Baseline resource use multiplied by real expenditure growth from 1997-2007 and change in budget share[8] from 1997-2007	Resource level to satisfy a share of consumption in 2007 taking into account real expenditure growth

Where *i* = resource intensive category (low, moderate, high); *r* = resource input (fossil fuel, land, water); q_{ir} = resource input *(r/kg)* for resource intensive category *i*; c_{0i} = weight of resource intensive consumption to total food consumption organised by resource intensity, per capita for category *i* in 1997; c_{1i} =c_{0i} as for 2007; Exp_{0i} = real expenditure growth between 1997 and 2007; Exp_{1i} = Product of Exp_{0i} and change in budget share between 1997 and 2007.

Table 6 reports three measures, drawing upon the terms from table 5, which are used to estimate differences in resource inputs through demand changes. Each measure is to be interpreted in terms of the additional resource input amount required to satisfy a given unit (measured in kilograms/litres) of an individual's consumption profile.

Table 6 Estimate Terms For Additional Resource Use

Number	Measure	Description
1	$\left(\sum_i D_{1ir} - \sum_i Base_i\right)$	Difference in resource requirement to produce a unit of food between consumption profiles of 1997 and 2007
2	$\left(\sum_i D_{2ir} - \sum_i Base_i\right)$	Difference in resource requirement accounting for the real expenditure growth between 1997-2007 for a constant consumption weight
3	$\left(\sum_i D_{3ir} - \sum_i Base_i\right)$	Difference in resource requirement accounting for both real expenditure growth and change in the budget share for a given change in consumption profile between 1997-2007

[7] See item III in appendix.
[8] See item IV in appendix.

Measure 1 provides an estimate for the resource requirement disparity on account of a change in the consumption weight alone. Measure 2 compares the resource requirement accounting for real expenditure growth alone between the two study periods. Measure 3 compares the resource requirement accounting for real expenditure growth, and changes in demand from 1997-2007.

3.5.1. Relative Resource Requirements

This approach computes the average relative growth factor in resource requirements for each of the resource intensive categories across inputs as

$$\gamma_{ir}=\frac{\alpha_{ir}}{low_r} \tag{9}$$

$$\bar{\gamma}_i = \frac{(\sum_r \gamma_{ir})}{3} \tag{10}$$

where *i* = low, moderate, high (food category); *r*= fuel, land, water (resource input); a_{ir} = resource input/kg output; low_r = resource input for low resource category; γ_{ir} = resource use relative to low; $\bar{\gamma}_i$ = average relative resource use across all inputs

This measure computes the relative resource use accounting for real expenditure growth and changes in the budget share from 1997-2007. Denote real expenditure growth by β_{0i} and real expenditure growth weighted by the change in budget share as β_{1i}. Taking the difference between the product of average relative resource use ($\bar{\gamma}_i$) with expenditure growth for resource category i, for constant (β_{0i}) and changed (β_{1i}) demand (expenditure share weighted by budget share change), demonstrates the relative amount of resources used for each category for the demand change. Aggregating these differences will produce the net relative difference in resource use

$$(Relative\ difference_i) = (\beta_{1i}\bar{\gamma}_i) - (\beta_{0i}\bar{\gamma}_i). \tag{11}$$

4. Results

4.1. Descriptive Statistics

Household demographic information concerning development characteristics are presented in table 7. The data covers 7,566 surveyed households in 1997, 10,256 in 2000 and 12,977 in 2007. Descriptive statistics highlight the impact that income and location (rural/urban) has upon key demographic variables. Poorer households are larger in size with a lower education level and a greater chance of being headed by a female. Rural households earn roughly three times less income per capita than urban counterparts. Therefore economic development is associated with households exhibiting higher education outcomes, smaller member sizes, more commonly headed by a male, to be found in an urban locality. The significant income gap between the poorest and richest quartiles will be a major factor in determining food consumption.

Table 7 Descriptive Statistics

	Pooled	Poorest (25%)	Richest (25%)	Rural	Urban
Household Size	6.01	6.19	5.35	5.82	6.19
Highest Education Level	4.81	3.91	5.96	3.99	5.67
Age of household head	46.56	49.16	43.74	46.84	46.25
Proportion of male headed household	0.82	0.74	0.88	0.82	0.81
Income per capita (annual)	8,188,074	166,338	30,300,000	4,279,000	12,300,000
=n	30799	7700	7699	12936	17863

4.2. Engel Curves[9]

Engel curves are first estimated for five food categories aligning with food items grouped by dietary means- staples, fruit/vegetables, dried food, animal products and condiments. Table 9 shows the food items corresponding to their respective dietary food category. Table 10 reports the elasticity coefficients for Lewbel's (2012) Engel curve estimation technique, where the variables of average household age, household head education level, rural-urban locality and household income are used to provide identification on household expenditure. The TSLS regression procedure shows that for a unit rise in household expenditure, the budget share falls most rapidly for staple food items and the least for animal products, consistently across 1997-2007. This indicates that as household expenditure rises (propelled from income), households spend less on staple food items relative to animal products. These results are illustrated graphically for 1997 in figure 1.

Table 9 Dietary Food Categories

Staple	Fruit & Veg	Dried Foods	Animal Products	Condiments
Rice	Green Vegetables (beans, spinach etc.)	Noodles, Rice noodles	Beef, buffalo, goat	Cooking Oil
Cassava/Tapioca	Fruits (banana, papaya etc.)	Other chips	Chicken, duck	Bottled Water
Sago/Flour		Tofu/Tempe	Fish, Oyster, Shrimp, Squid	Granulated Sugar
Other Staples (potatoes, yams)			Salted Fish	Salt
			Milk (fresh, canned, condensed)	

[9] See appendix item V for dietary and resource Engel curves (1997-2007). The drawn Engel curves omit outliers beyond 2 standard deviations from the mean.

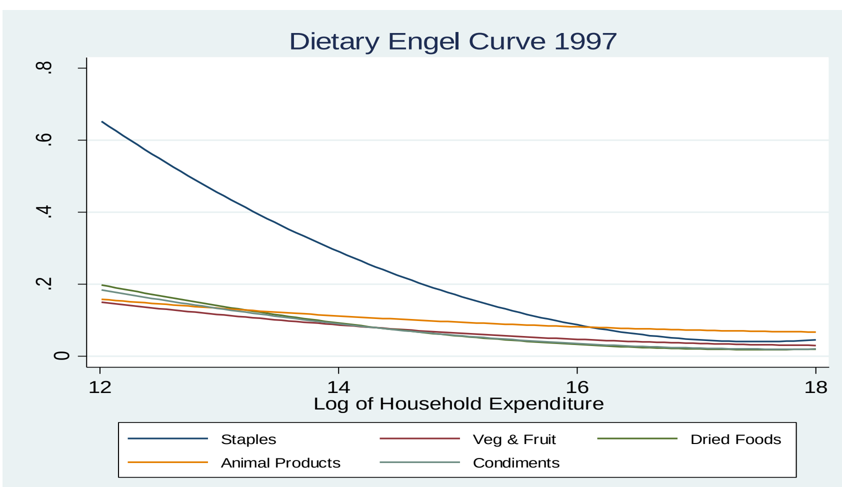
These results show that household behaviour is consistent with the general nature of developing country food demand discussed in the introduction. For a rising expenditure (income), households will allocate a greater share of expenditure towards animal and processed goods at the expense of traditionally consumed staples. Such an outcome is consistent with a convergence to affluent consumption patterns of developed countries. This is significant as subsequent estimation concerning resource requirements is underpinned by these results confirming from the dietary perspective, the empirical consensus linking economic development and food favouring affluent, westernized consumption patterns. Therefore any significant results when analysed from a resource intensive perspective for Indonesia may also be appropriate for other developing countries, strengthening the significance of forthcoming results.

Table 10 Engel Expenditure Share Coefficients For Dietary Food Categories*

Food Category	1997	2000	2007
Staple	-0.582	-0.708	-0.707
Vegetable/Fruit	-0.361	-0.287	-0.56
Dried Food	-0.478	-0.435	-0.682
Animal Products	-0.202	-0.024	-0.331
Condiments	-0.466	-0.422	-0.61

*All significant at the 1% level or greater

Figure 1 Dietary Engel Curve for 1997



The estimation of Engel curves for the three resource intensive food categories (see table 2) demonstrate the implications of economic development for resource use. The Lewbel (2012) technique, with the same vector of exogenous variables *(Z)* is again used in estimation. The resource intensive TSLS regression results are presented in table 11. These results show that for a rising household expenditure, the proportion of expenditure on low resource intensive items falls by a consistently higher amount, compared to moderate and high resource counterparts. A challenging result exists for the coefficient of the high resource food category for 2000, being significantly lower in comparison to the other years. This abnormally small coefficient may be explained by the depressed economic conditions within

Indonesia during this time which suppressed levels of high resource intensive food consumption, and a negligible effect on the budget share for a rising expenditure. The resource intensive Engel curve for 1997 is displayed in figure 2.

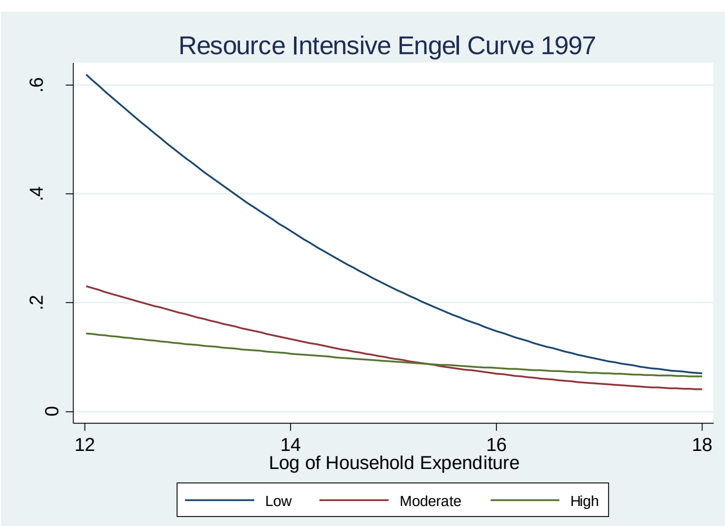
Table 11 Engel Expenditure Share Coefficients for Resource Intensive Food Categories*

Food Category	1997	2000	2007
Low Resource	-0.397	-0.541	-0.717
Moderate Resource	-0.33	-0.333	-0.549
High Resource	-0.181	-0.008	-0.5

*All results significant at the 1% level or greater

Therefore, for rising expenditure, a household will allocate a greater share of expenditure towards high resource intensive items. This is confirmed through the magnitude of the expenditure change, whereby real expenditure grew by a factor of 1.13 for low resource items, compared to 1.46 and 1.29 respectively for moderate and high items. Despite the falling budget shares across each of the resource intensive (and dietary) categories consistent with Engel's law, the absolute amount of real expenditure has still increased over the study period. While real expenditure growth occurs across all three resource intensive groups for an increase in household expenditure, this growth is most significant for high resource intensive items. These findings have profound implications considering that the process of economic development, a key driver of household expenditure, is associated with higher expenditure levels towards food items requiring more resources in production. Notwithstanding the important benefits of economic development, these results suggest that this process will also accelerate the demand for scarce resources. The need for policy to manage resource scarcity amidst the range of issues stemming from food demand emerges from this, and is treated in more detail at the end of this section.

Figure 2 Resource Intensive Curve for 1997



4.3. Elasticity

The log-log model outlined in section 3.4 allows for weighted income elasticities to be calculated for the sample. Results by rural/urban location and income quartiles, in addition to the aggregate sample are reported in table 12. For the aggregate sample, income elasticity rises with the level of resource intensity, as defined through the three categories. The elasticity measures remain similar between the survey waves, dismissing any strong dynamic effects on Indonesian food demand patterns over the period considered.

Table 12 Income Elasticity (Weighted)*

Food Group	Year	Pooled (Aggregate)	Rural	Urban	Income Quartile 1	Income Quartile 2	Income Quartile 3	Income Quartile 4
Low	1997	0.078	0.056	0.112	0.035	0.218	0.089	0.223
	2000	0.082	0.065	0.099	0.015	0.157	0.084	0.057
	2007	0.071	0.065	0.078	0.005	0.147	0.112	0.059
Moderate	1997	0.089	0.082	0.099	0.028	0.3116	0.151	0.133
	2000	0.089	0.077	0.097	0.045	0.146	0.114	0.019
	2007	0.084	0.083	0.083	-0.011	0.067	0.204	0.086
High	1997	0.113	0.108	0.119	0.062	0.322	0.170	0.227
	2000	0.103	0.087	0.116	0.017	0.142	0.242	0.066
	2007	0.098	0.097	0.100	-0.014	0.189	0.245	0.113

*All results are significant at the 10% level or greater

The results show that income elasticity depends on the location of the household. Urban households display higher income elasticity across all three resource categories. For example in 2000, a unit change in income will result in a 8.7% increase in the quantity demanded for the high food resource group by a rural household, compared to a 11.6% increase from an urban household. Higher income elasticity for urban households is supported by the descriptive statistics analysis, showing that urbanised households have a higher attainment of development indicators compared to rural households. The elasticity results are therefore consistent with the premise of food demand being linked to regional development within Indonesia (Pangaribowo and Tsegai (2011). Nevertheless, in both rural and urban localities high resource intensive food items are associated with larger income elasticities.

Analysis by income quartiles highlights the impact of income upon demand patterns across the food categories. The poorest households (quartile 1) have abnormally low elasticity figures across all waves. This result defies the expected results according to Engel law, where a poorer household is expected to allocate a significant share of any additional income towards food consumption. Households in the second and third quartiles actually display the highest income elasticity (as high as 0.32), allocating a greater share of additional income towards food relative to poorer households. This challenging result may be explained by the income level recorded across many of the poorest households as being zero or even negative[10]. This may impact upon the integrity of elasticity estimation given the significant presence of zero income entries which bias the OLS estimation. The wealthiest households' income elasticity is lower in comparison to middle income counterparts, yet still higher than the poorest households. This indicates that the wealthiest households will allocate a smaller share of additional income to food relative to those in lower income brackets. This is not to say that the absolute level of expenditure will also be lower.

Therefore as a household gets richer, s/he will display a greater tendency to spend additional income on food items that are more resource intensive to produce. This effect is mitigated once the household falls into the highest income quartile. This suggests that income elasticity growth approaches a level of saturation with respect to income. As illustrated through the Engel curves, a household with high levels of expenditure will already be favouring higher resource intensive food items relative to a poorer household. Furthermore, food items displaying the greatest resource input requirements are consistently associated with higher income elasticities across all income levels. This indicates that households display stronger demand towards food items with higher resource needs in production.

The implications stemming from food demand orientated towards a higher degree of resource input are broad. Rising food prices on account of scarce resource input, acceleration of environmental degradation and economic incentives to engage in comparatively inefficient food production are just some significant consequences potentially arising from the Indonesian food demand patterns. These results are therefore important in exposing the range of challenges that emancipate from economic development relating to natural resource management, given that no previous studies have forged a direct link between food demand patterns being more resource intensive on account of economic development.

4.4. Additional Resource Use

The estimated coefficients from Engel and income elasticity of demand analysis provide strong evidence that economic development favours food demand patterns that are more resource intensive. However, the estimated coefficients do not provide quantification of the additional amount of resources used over the study period that are attributable to changed demand. This section offers intuitive measures in detailing the net effects of demand on per-capita resource use in both absolute and relative terms.

Table 13 reports on the absolute per capita resource needs across the three inputs and estimate terms developed in section 3.5. Estimate 1 $(\sum_i D_{1ir} - \sum_i Base_i)$ measures the additional resource input required per kg of average consumption for the change in an individual's consumption share of the three resource intensive food groups over 1997-2007. Estimate 2 $(\sum_i D_{2ir} - \sum_i Base_i)$ calculates the difference in the resource input necessary to satisfy food consumption relative to the 1997 requirement in accounting for real expenditure growth over the study period. Estimate 3 $(\sum_i D_{3ir} - \sum_i Base_i)$ shows the additional resource use required relative to the 1997 input requirement considering real expenditure

[10] There were 1,405 household in 1997; 1,154 in 2000; and 1,980 in 2007 where a per capita annual income was recorded to be at or below zero. A negative income is possible given that the income variable was indirectly constructed from a range of other variables, as no definitive measure of household income was provided.

growth and changes to both consumption and budget shares of the resource intensive categories over the period studied. See appendix item VI for the input numbers into each of these terms.

The results show that changes in food demand, empirically established through the estimation of Engel curves and income elasticities, do indeed require more absolute resource inputs in terms of fossil fuels, land and water. All results are non-negative, aside from estimate 1 for the moderate resource intensive category on account of the fall in consumption share for this category from 1997-2007. The definitive estimate 3 reports that on a per-capita basis, changes in demand measured through consumption and budget shares, accounting for real expenditure has resulted in the amount of fossil fuels (MJ's), land (m^2) and water (KL) resource inputs be 3.13, 1.24 and 2.103 units greater respectively, in order to satisfy consumption relative to the base period.

Table 13 Estimate Results For Additional Resource Use (Absolute[11])

	Estimate 1 ($\sum_i D_{1ir} - \sum_i Base_i$)			Estimate 2 ($\sum_i D_{2ir} - \sum_i Base_i$)			Estimate 3 ($\sum_i D_{3ir} - \sum_i Base_i$)		
	Fuel	Land	Water	Fuel	Land	Water	Fuel	Land	Water
Low	0.05	0.02	0.017	0.19	0.08	0.069	0.08	0.03	0.029
Moderate	-0.32	-0.06	-0.076	0.97	0.18	0.229	0.81	0.15	0.191
High	0.55	0.25	0.449	1.09	0.51	0.915	2.24	1.06	1.882
Aggregate	0.26	0.21	0.39	2.25	0.78	1.213	3.13	1.24	2.103

Furthermore the additional amount of resources used on account of changing demand patterns is examined in relative terms. Table 14 reports the aggregate relative resource measure for the average of the relative resource input intensity between the three categories. The base case is inclusive of real expenditure growth over the study period, and is compared to the outcome where the budget share of expenditure is allowed to vary, representing changed demand. The resulting terms are interpretable as relative resource units, rather than reference to a specific amount of resource input.

Table 14 Estimate Results For Additional Resource Use (Relative)

Food group	No Demand Change ($\beta_{0i}\bar{\gamma}_i$)	Changed Demand ($\beta_{1i}\bar{\gamma}_i$)	Difference ($\beta_{1i}\bar{\gamma}_i$ - $\beta_{0i}\bar{\gamma}_i$)
Low	1.13	1.02	-0.11
Mod	3.51	3.93	0.42
High	21.35	23.13	1.78
Sum	25.99	28.08	2.09

These results show the net effect of changed demand patterns leading to an outcome where approximately 1.08 times (8%) as many resources are required relative to the status quo. The softer demand for low resource intensive items sees relatively fewer resources being required to satisfy this resource category. These effects are more than offset by the growth in demand for moderate and high resource intensive categories, with the aggregate value reflecting this.

[11] See appendix item VI for detail into the absolute input requirements.

It is expected that any growth in real food expenditure will command an increase in the amount of resources necessary to supplement production. The quantification both in absolute and relative terms demonstrate for the study period while controlling for changes in real expenditure, that demand patterns lead to a greater amount of resource use being commanded on a per-capita basis within Indonesia.

These results must be considered in the context of the increase in Indonesia's population by some 34.1 million people over the study period. This growth compounds the effect of rapid economic development, serving to place immense pressure on global resource inputs in agricultural supply chains to meet Indonesia's growing affluent food consumption profile. These results will quite possibly reflect a similar trend in other Asian countries, highlighting the need for further empirical research. Such research into other developing countries (especially in the Asian region where the strongest levels of population growth are expected) demand for resource intensive foods will provide important evidence into the pressures that economic development is having upon finite natural resources.

4.5. Limitations of the study

There are some important limiting factors which underpin the methods in this study. The quality of food consumed over the study period has not been accounted for, a factor that can affect dynamic food demand. The availability of food substitutes, as well as intertemporal household consumption factors have not been included in the demand model, which may impact upon the nature and magnitude of results. Furthermore, the log-log OLS model used to estimate income elasticities is limiting in the sense of being a partial demand model. The specification of a complete demand system, such as Deaton and Muellbauer's (1980) 'Almost Ideal Demand System' would provide greater consistency with the axioms of consumer demand theory.

This paper has also made the significant assumption that resource inputs into agricultural food production remain constant over the study period. Improved production technology, or the use of increasingly marginal resource inputs are factors which will serve to influence the input requirements over the study period. It is therefore highly unlikely to expect resource input requirements to remain static through time. In fact, the method by which the resource input figures were produced for the case of Indonesia proceeded without the guidance of any previously established methodology. The accuracy of the 'back of the envelope' method employed when estimating the resource input intensity would be improved if an index, recognising factors such as resource price, environmental cost and productivity, in the context of different production regions, was applied. This would also improve the integrity behind the quantification of the additional resource input use over time, in providing a greater level of rigour behind the input requirements reflective of regional differences. Admittedly the quest to obtain an accurate index controlling for heterogeneous regional effects relating to resource scarcity, input intensity and price may be a heroic ambition, considering the extensive scope of factors which such a measure would need to capture.

5. Conclusion

This paper presents an analysis of food demand patterns of Indonesian households from the perspective of resource intensity of food items. Results from both the Engel curve and income elasticity of demand estimations show that households demand food items that require a greater amount of resource inputs. These demand effects are exemplified when considered across different income levels and locations, consistent with economic development. The paper also sought to provide a quantification of the additional amount of resource inputs used on account of demand patterns over the study period. After controlling for real expenditure growth, these results show that fossil fuel, land and water input requirements rise significantly over the study period as a result of changes to demand.

These results generate considerable challenges for policy concerning the management of natural resources. By establishing a link between economic development and increased natural resource use, this research motivates inquiry into economic policies concerning the mitigation of pressures on natural resources, on account of changing food demand patterns. Such research should consider the implications of policies addressing supply and/or demand side approaches concerning the management of the food system in the context of resource use. Alternatively, an appraisal of the natural transitions stemming from the free-market mechanism, functioning as an economic institution, and the associated welfare implications could be considered. These further policy studies become particularly important considering that the transition towards affluent food consumption patterns in current developed nations occurred at a gradual rate, relative to the rapid changes in economic restructuring and hence food demand currently occurring in developing countries (Gerben-Leens et. al 2010). Therefore the avenues for future research are motivated by the normative objectives of achieving a sustainable, accessible, available and secure food system in the context of economic development and increased resource scarcity.

This study also has highlighted a range of areas where a lack of knowledge has constrained a more comprehensive assessment of food demand from a resource intensive perspective. Further research into the development of a resource intensity scale or index for food items which recognises spatial effects across a variety of inputs would significantly improve the level of rigour in the components of research which rely upon application of organising foods by measure of resource use. The methodology behind the index would have to trade off elements of accuracy in the interests of feasibility, given the difficulty in accounting for every factor impacting on resource use in production between different regions.

This study provides an ideal platform to conduct similar empirical analysis into other developing countries regarding food demand and resource use in order to strengthen the consensus that economic development is associated with food demand patterns that are more resource intensive. Through highlighting the stark disparities in the resource inputs necessary to produce different food items, this paper suggests that without appropriate policy responses, demand patterns following economic development will impact on food affordability, access and environmental degradation. This suggests that the ideals of development may promote a future where food security is an inhernintely difficult objective to achieve on account of the change in demand towards more resource intensive foods.

References

Baum, C.F., Lewbel, A., Schaffer, M.E., and Talavera, O. (2013). Instrument variables estimation using heteroskedasticity-based instruments. Presentation at the German Stata Group Meeting, Postam. Available at: http://www.stata.com/meeting/germany13/abstracts/materials/de13_baum.pdf (accessed 2 August 2013).

Blandford, D. (1984). Changes in food consumption patterns in the OECD area. *European Review of Agricultural Economics* 11(1), 43-64.

Blundell, R., Duncan, A., and Pendakur, K. (1998). Semiparametric estimation and consumer demand. *Journal of Applied Econometrics* 13(5), 435-461.

Chang, S.H., Socheth, H., Chandarany, O., Dalis, P., and Dorina, P. (2012). *Foreign Investment in Agriculture in Cambodia.* CDRI Working Paper Series No. 60, Food and Agriculture Organisation of the United Nations. T & S Printing, Phnom Penh.

Deaton, A., and Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review 70*(3), 312-326.

Deaton, A. (1985). *Three essays on a Sri Lanka household survey*. World Bank Development Research Center, Washington.

Deaton, A. (1990). Price elasticities from survey data: extensions and Indonesian results. *Journal of Econometrics* 44(3), 281-309.

Deaton, A., and Zaidi, S. (2002). *Guidelines for constructing consumption aggregates for welfare analysis*. World Bank Publications, Washington.

Dixon, J.A. (1982). *Food Consumption Patterns and Related Demand Parameters in Indonesia: a review of available evidence (Working Paper)*. International Food Policy Research Institute, Washington.

Dyck, J., Woolverton, A.E., and Rangkuit, F.H. (2012). *Indonesia's Modern Food Retail Sector: Interaction With Changing Food Consumption and Trade Patterns.* U.S. Department of Agriculture, Economic Research Service, EIB-97.

Emran, M.S., and Hou, Z. (2013). Access to markets and rural poverty: evidence from household consumption in China. *Review of Economics and Statistics* 95(2), 682-697.

Engel, E. (1857). Die Produktions-und ConsumtionsverhÄaltnisse des KÄonigreichs Sachsen. Reprinted in *Bulletin de Institut Interational de Statistique* (1895) 9, 1-54.

Engel, J., and Kneip, A. (1996). Recent approaches to estimating Engel curves. *Journal of Economics* 63(2), 187-212.

Fabiosa, J.F., Jensen, H.H., and Yan, D. (2005). *Household Welfare Cost of the Indonesian Macroeconomic Crisis.* Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Rhode Island. Available at: http://ageconsearch.umn.edu/bitstream/19311/1/sp05fa01.pdf (accessed 30 March 2013).

FAO (2000). *The Energy and Agriculture Nexus.* Food and Agriculture Organisation of the United Nations, Environment and Natural Resources Working Paper No. 4, Rome.

FAO (2002). *Crops and drops: making the best use of water for agriculture*. Food and Agriculture Organisation of the United Nations, Rome.

FAO (2011). *FAOSTAT Database.* Food and Agriculture Organisation of the United Nations, Rome. Available at http://faostat.fao.org/site/291/default.aspx (accessed 21 June 2013).

Gerbens-Leenes, P., Nonhebel, S., and Ivens, W. (2002). A method to determine land requirements relating to food consumption patterns. *Agriculture, ecosystems and environment* 90(1), 47-58.

Gerbens-Leenes, P., Nonhebel, S., and Krol, M. (2010). Food consumption patterns and economic growth. Increasing affluence and the use of natural resources. *Appetite* 55(3), 597-608.

Gleick, P.H. and Cooley, H.S. (2009). Energy implications of bottled water. *Environmental Resource Letters* 4(1), 014009.

Herrmann, R., and Röder, C. (1995). Does food consumption converge internationally? Measurement, empirical tests and determinants. *European Review of Agricultural Economics* 22(3), 400-414.

Howe, H., Pollak, R.A., and Wales, T.J. (1979). Theory and time series estimation of the quadratic expenditure system. *Econometrica* 47(5), 1231-1247.

Jensen, H.H., and Manrique, J. (1998). Demand for food commodities by income groups in Indonesia. *Applied Economics* 30(4), 491-501.

Kakwani, N. (1977). On the estimation of Engel elasticities from grouped observations with application to Indonesian data. *Journal of Econometrics* 6(1), 1-19.

Kneip, A. (1994). Nonparametric estimation of common regressors for similar curve data. *The Annals of Statistics* 22(3) 1386-1427.

Leser, C.E.V. (1963). Forms of Engel functions. *Econometrica* 31(4), 694-703.

Lewbel, A. (2012). Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. *Journal of Business and Economic Statistics* 30(1), 67-80.

Liu, J., and Savenije, H.H.G. (2008). Food patterns and their effect on water requirement in China. *Hydrology and Earth System Sciences* 12, 887-898.

Meghir, C., and Robin, J.M. (1992). Frequency of purchase and the estimation of demand systems. *Journal of Econometrics* 53(1), 53-85.

Mishra, V., and Smyth, R. (2012). *Returns to Schooling in Urban China: New Evidence Using Heteroskedasticity Restrictions to Obtain Identification Without Exclusion Restrictions.* Discussion Paper 33/12, Monash University. ISSN 1441-5429.

Pangaribowo, E.H., and Tsegai, D. (2011). *Food Demand Analysis of Indonesian Households with Particular Attention to the Poorest*. ZEF Discussion Papers on Development Policy No. 151, Center for Development Research, Bonn. ISSN 1436-9931.

Pimental, D., and Pimental, M. (1979). *Food, energy and society*. Edward Arnold, London.

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., and Alpert, S. (1997). Water resources: agriculture, the environment, and society. *BioScience*, 47(2), 97-106.

Pimentel, D. (2006). *Impacts of organic farming on the efficiency of energy use in agriculture*. Organic Center State of Science Review. Available at http://organic.insightd.net/reportfiles/ENERGY_SSR.pdf (accessed 7 April 2013).

Pimentel, D., and Pimentel, M.H. (2007). *Food, energy, and society* (3rd ed.). Crc Press, Boca Raton.

Popkin, B. M. (2006). Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *The American Journal of Clinical Nutrition* 84(2), 289-298.

Rae, A.N. (1997). Changing food consumption patterns in East Asia: implications of the trend towards livestock products. *Agribusiness* 13(1), 33-44.

Reardon, T., Timmer, C.P., and Minten, B. (2012). Supermarket revolution in Asia and emerging development strategies to include small farmers. *Proceedings of the National Academy of Sciences of the United States of America* 109(31), 12332-12337.

Regmi, A., Takeshima, H., and Unnevehr, L. (2008) Convergence in food demand and delivery: do middle-income countries follow high-income trends? *Journal of Food Distribution Research* 39(1), 116-122.

Sainz, R.D. (2003). *Livestock-environment initiative fossil fuels component: Framework for calculating fossil fuel use in livestock systems.* FAO Livestock Environment and Development. Available at http://www.fao.org/WAIRDOCS/LEAD/X6100E/X6100E00.HTM (accessed 30 June 2013).

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice. C., Scholes B, and Sirotenko, O. (2007). Agriculture. In: Metz, Davidson, O.R., Bosch, P.R., Dave, R., and Meyer L.A. (eds) *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of theIntergovernmental Panel on Climate Change,* pp. 497-540. Cambridge University Press, New York.

Strauss, J., Witoelar, F., Sikoki, B., and Wattie, A.M. (2009). *The Fourth Wave of the Indonesian Family Life Survey (IFLS4): Overview and Field Report.* WR-675/1-NIA/NICHD, RAND Corporation, Washington.

Tambunan, T. (2006). Long term trends in the industrial and economic growth in Indonesia. *Center for Industry and SME Studies (Working Paper Series No. 11),* University of Trisakti Indonesia.

Timmer, C.P., and Alderman, H. (1979). Estimating consumption parameters for food policy analysis. *American Journal of Agricultural Economics* 61(5), 982-987.

Toiba, H., Umberger, W.J., Minot, N., and Stringer, R. (2012). Dietary Transformation in Indonesia: Is the "Supermarket Revolution" to Blame? *Agricultural and Applied Economics Association,* Annual Meeting August 12-14, Seattle, Washington, No. 124802. Available at: http://purl.umn.edu/124802 (accessed 25 May 2013).

Tzilivakis, J., Warner, D., May, M., Lewis, K., & Jaggard, K. (2005). An assessment of the energy inputs and greenhouse gas emissions in sugar beet *(Beta vulgaris*) production in the UK. *Agricultural Systems* 85(2), 101-119.

UNDESA (2012). *World Urbanization Prospects: The 2011 Revision.* United Nations Department of Economic and Social Affairs, New York.

UNDESA (2013). *World Fertility Data 2012 (POP/DB/Fert/Rev2012)*. United Nations, Department of Economic and Social Affairs, Population Division, New York.

UNSD (2013). *UNdata: A world of information* (statistical database). United Nations Statistical Division, Department of Economic and Social Affairs, New York. Avaialbe at http://data.un.org/ (accessed 30 August 2013).

Widodo, T. (2006). Demand estimation and household's welfare measurement: case studies on Japan and Indonesia. *Hiroshima University of Economics Journal of Economic Research* 29(2), 103-136.

Woods, J., Williams, A., Hughes, J.K., Black, M., and Murphy, R. (2010). Energy and the food system. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1554), 2991-3006.

Working, H. (1943). Statistical laws of family expenditure. *Journal of the American Statistical Association* 38(221), 43-56.

Appendix

Item I IFLS Variables in Demand Analysis

Variable Name	Units	Description	Household/ Community Level
Quantity Consumed	Kilograms or Litres	Annual per-capita consumption of food item	Household
Food Price	Indonesian Rupiah (IDR)	Per-unit price of food item	Community
Income	IDR	Annual per-capita income	Household
Household Size	Persons	Size of household in persons	Household
Rural/Urban	Dummy	0 (rural) & 1 (urban) location of household	Household
Education Level of Household Head	Education Scale (1-9)	Records highest level of education completed by household head where 1 refers to elementary school and 9 refers to doctoral qualification	Household
Sex of Household Head	Dummy	0 (female) & 1 (male)	Household
Average Age of Household	Years	Average age of all household members	Household
Economic Shock	Dummy	0 (no) & 1 (yes) for an economic shock being experienced in the last 5 years	Household
Household Head Marital Status	Dummy	0 (not married/other) & 1 (married) for household head	Household
Religion	Dummy	0 (all other) & 1 (Islamic) religion practising household	Household
Child Share in Household	Percentage Units	Share of household members classified as a child (<15yrs)	Household
Adult Share in Household	Percentage Units	Share of household members classified as an adult(16-60yrs)	Household
Senior Share in Household	Percentage Units	Share of household members classified as a senior(>60yrs)	Household
Major Share of Income	Dummy	Vector of dummy variables reporting on the major source of income being from farm, asset, non-labour, self-employment, salary or transfers	Household
Community Size	Hectares	Size of village in hectares	Community
Slums in Community	Dummy	0 (no slums) 1 (slums) exist in the village	Community
Population of Community	Persons	Population of the community	Community
Average Household Size in Community	Persons	Average size of households within community	Community
Presence of	Dummy	0 (no institution) & 1 (at least one	Community

Financial Institution		institution)	
Presence of Market	Dummy	0 (no market) & 1 (at least one market)	Community
Presence of Factory	Dummy	0 (no factory) & 1 (at least one factory)	Community
Village Midwife	Dummy	0 (no midwife) & 1 (midwife)	Community
Medicine Post (Clinic)	Dummy	0 (no post) & 1 (medicine post)	Community
Road Condition	Dummy	0 (mostly non-sealed roads) & 1 (mostly sealed roads)	Community
Drinking Water Source	Dummy	0 (other sources) & 1 (water can be accessed by tap or pump)	Community

Item II Food Items and Individual Resource Inputs

Resource Category	Food Item	Fossil Fuels (MJ/kg)	Water (L/kg)	Land (m^2/kg)
Low	Rice	6.91 [a, b, c]	1912 [j]	2.12 [g]
	Cassava		1240 [h]	1 [g]
	Potatoes/other Staples	4.75 [c]	500 [j]	0.63 [g]
	Sago/Flour	2.02 [d]		0.77 [g]
	Vegetables	0.81 [c]	190 [h]	0.83 [g]
	Fruits	2.16 [c]	500 [h]	0.64 [g]
Moderate	Noodles, rice noodles, shrimp chips, other chips	5.17 [b]	900 [j]	
	Tofu, Tempe	12 [b]	5000 [h]	2.66 [h]
	Granulated sugar	14.1 [d]	1020 [h]	0.164 [g]
	Fresh, canned, condensed milk	16.2 [b]	1000 [h]	1.7 [b]
	Salt	2.5 [e]		
	Salted Fish[b]			
High	Beef	37.5 [b]	100000 [j]	31.46 [b]
	Poultry	27.8 [b]	2390 [h]	7.26 [b]
	Fish/Seafood	33.61 [d]	5000 [h]	9.68 [b]
	Cooking Oils		5080 [h]	2 [b]
	Bottled Water	5.6-10.2 [f]	1	

Sources: a = FAO (2000) b = Sainz R.D. (2003) c = Pimentel (2006) d = Pimentel and Pimentel (2007) e = (Tzilivakis et. al 2005) f = Gleick and Cooley (2009) g = FAO (2011) h = Chang et. al (2012) i = Liu and Savenije (2008) j = Pimentel et. al (1997)

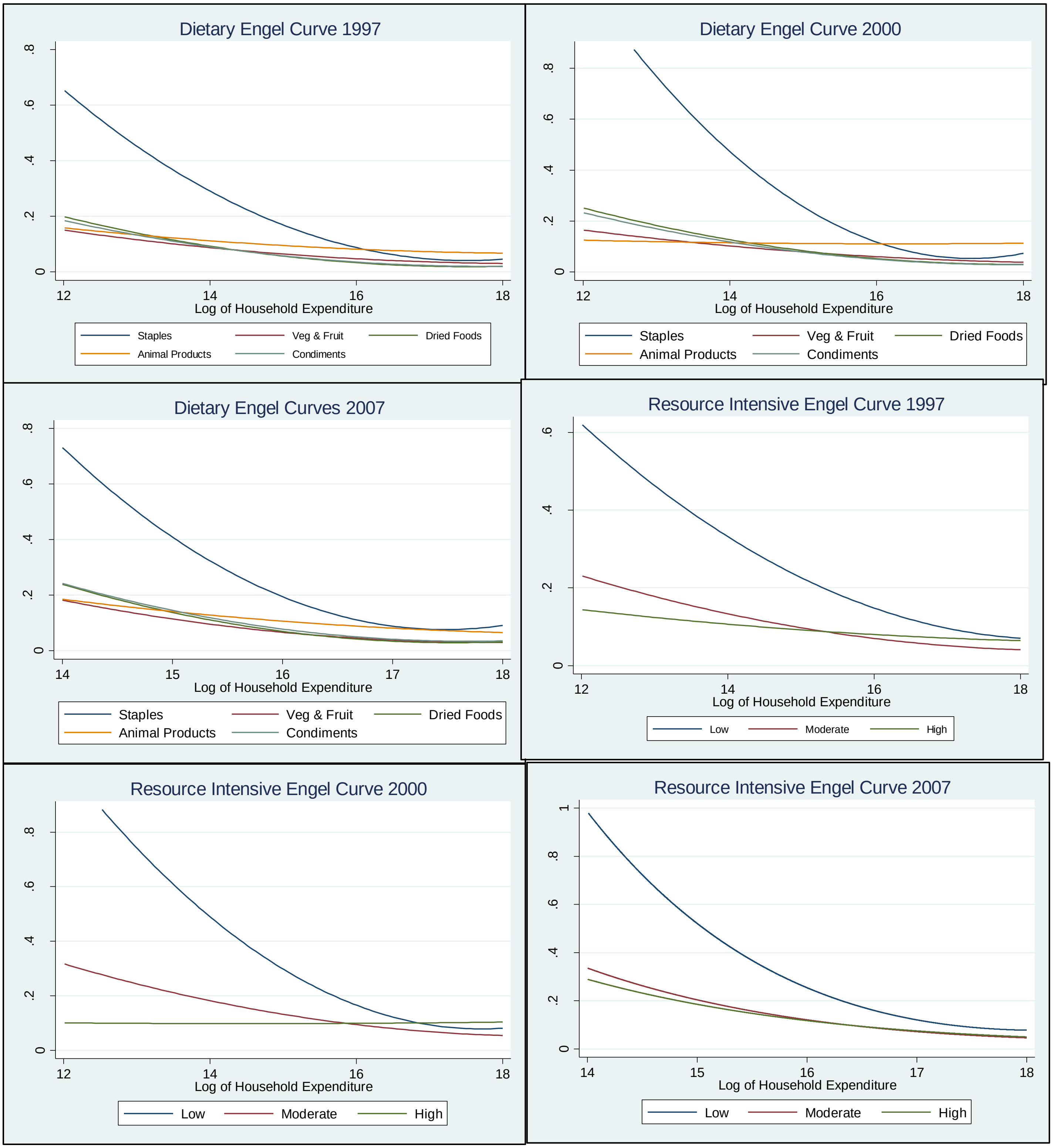
Item III Household Real Expenditure Growth Across Resource Categories

HH Exp (IDR) annual	1997	2000	2007	Growth Factor 97-07 (Exp_0)
low	983,614	1,614,991	1,114,609	1.13
mod	507,452	911,367	742,058	1.46
high	567,241	1,000,827	732,059	1.29

Item IV Household Food Budget Shares For Food

Budget Shares on Food	1997	2000	2007	Change 97-07
low	0.51	0.48	0.46	0.90
mod	0.25	0.28	0.28	1.12
high	0.24	0.24	0.26	1.08

ITEM V Engel Curves – Dietary and Resource (1997-2007)



Item VI Input Figures For Absolute Net Resource Use (table 13)

Fuel	**$q_{i, fuel}$**	**C_{0i}**	**C_{1i}**	**$Base_i$**	**D_{1i}**	**D_{2i}**	**D_{3i}**
Category (i)	Input (MJ/kg)	Consumption weight (1997)	Cons. Weight (2007)	$q_{ir}c_{oi}$	$q_{ir}c_{1i}$	$Base_iExp_{0i}$	$Base_iExp_{1i}$
Low	2.35	0.6	0.62	1.41	1.457	1.598	1.49
Mod	8.08	0.26	0.22	2.10	1.7776	3.07	2.91
High	26.73	0.14	0.16	3.74	4.2768	4.83	5.98
Sum	**37.16**	**1**	**1**	**7.25**	**7.5114**	**9.5**	**10.38**

Land	**$q_{i, fuel}$**	**C_{0i}**	**C_{1i}**	**$Base_i$**	**D_{1i}**	**D_{2i}**	**D_{3i}**
Category (i)	Input (MJ/kg)	Consumption weight (1997)	Cons. Weight (2007)	$q_{ir}c_{oi}$	$q_{ir}c_{1i}$	$Base_iExp_{0i}$	$Base_iExp_{1i}$
Low	1.02	0.6	0.62	0.61	0.63	0.69	0.64
Mod	1.51	0.26	0.22	0.39	0.33	0.57	0.54
High	12.6	0.14	0.16	1.76	2.01	2.28	2.82
Sum	**15.13**	**1**	**1**	**2.76**	**2.98**	**3.54**	**4.01**

Water	**$q_{i, fuel}$**	**C_{0i}**	**C_{1i}**	**$Base_i$**	**D_{1i}**	**D_{2i}**	**D_{3i}**
Category (i)	Input (MJ/kg)	Consumption weight (1997)	Cons. Weight (2007)	$q_{ir}c_{oi}$	$q_{ir}c_{1i}$	$Base_iExp_{0i}$	$Base_iExp_{1i}$
Low	0.868	0.6	0.62	0.521	0.538	0.59	0.55
Mod	1.908	0.26	0.22	0.496	0.420	0.726	0.687
High	22.494	0.14	0.16	3.149	3.599	4.064	5.031
Sum	**25.271**	**1**	**1**	**4.166**	**4.557**	**5.38**	**6.268**