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Economic development, food demand and the consequences for agricultural resource requirements: an application to Indonesia

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We analyse food demand patterns of Indonesian households from a resource intensity perspective and quantify the impact of changed demand patterns on the use of three major resource inputs: fossil fuel; land; and water in agricultural production. Using Indonesian Family Life Survey data, 13 major food items (which constitute 70 per cent of food expenditure) are categorised into low, moderate and high resource intensity, and income elasticity and Engel curves are estimated for the period from 1997 to 2007. Our results show that income growth in Indonesia is associated with demand patterns that are more resource intensive. By 2007, per capita requirements of fossil fuel, land and water increased by 42.7 per cent (3.13 MJ), 44.9 per cent (1.24 m^2) and 50.4 per cent (2.1 kL), respectively, relative to 1997. The results imply that, at least for Indonesia, changed food demand patterns resulting from economic development will increase the demand for natural resources substantially.

Key words: demand analysis, economic development, Indonesia, natural resource management.

1. Introduction

In this paper, we analyse the implications of change in food demand patterns of Indonesian households from a resource intensity perspective. Food demand is a core element of household behaviour strongly affected by economic development. Economic development underpinned by income growth drives changing food consumption patterns, reflective of emerging tastes and preferences for various food items. The literature has documented the changing nature of food demand in developing countries, characterised by increased consumption of meat and processed goods at the expense of traditional staple items (Blandford 1984; Herrmann and Röder 1995; Rae 1997). Diverse empirical findings suggest convergence towards affluent 'westernised' consumption patterns on account of economic development for developing countries (Popkin 2006; Regmi *et al.* 2008). However, conventional analysis of dietary food demand risks overlooking wider implications. This paper extends existing analysis to consider the impacts of

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changing food demand patterns in developing countries upon natural resource use.

Approximately 50 per cent of land (Smith *et al*. 2007), 70 per cent of water (FAO 2002) and 3 per cent of fossil fuel consumption, encompassing 10–12 per cent of greenhouse gas emissions (Smith *et al*. 2007; Woods *et al*. 2010), are used globally for agricultural production activities. However, not all agricultural activities are equal; the seminal work of Pimentel and Pimentel (1979) shows the disparities in resource input requirements across food items. This is particularly important for developing countries as they account for the largest change in food consumption patterns (Gerbens-Leenes *et al*. 2010). The income growth associated with economic development relaxes budget constraints, enabling households to purchase a wider range of food items often associated with high resource input requirements.

We look at: (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 through demand changes over time. Given agriculture's significant use of major global resources, analysing the nature of demand patterns from a resource use perspective is imperative, especially for developing countries.

We consider the developing economy of Indonesia, which has experienced significant changes in food demand patterns. Factors such as strong GDP growth per capita (3.7 per cent per annum for 1970–2011, Tambunan 2006; UNSD 2013), rapid rural–urban migration (4.6 per cent per annum from 1995 to 2010, UNDESA 2012) and improved literacy rates (from 75.3 per cent in 1990 to 86.8 per cent in 2007, UNSD 2013) have all contributed to changes in food demand.[1]

Given these changes, it is appropriate to consider whether economic development is associated with more resource intensive food demand patterns in Indonesia. The long-run nature of the Indonesian Family Life Survey (IFLS) data used in this research spanning 10 years is also conducive to estimate the net change in resource use that we link to food demand changes.[2] After organising food items based on measures of resource intensity, demand estimation techniques are used to demonstrate the absolute and relative changes in resources over the study period that would be required to meet demand changes. We find that economic development generates a more resource intensive food demand profile.

Our paper provides the first country-specific study linking economic development, food demand and agricultural resource requirements. While economic development is desirable from perspectives of economic well-being,

[1] These factors have increased the shadow value of home production and the preference for leisure, influencing household food preferences away from traditional staple food items.

[2] As discussed in Section 3, our analysis is limited to 1997–2007 IFLS rounds. The analysis remains valid post-2007 because core food demand factors remain comparable between the period that we considered and post-2007.

the implications placed on natural resources as elicited by changed demand patterns require attention. The results question the paradigm of 'development' from a food demand perspective, and what developing (and developed) countries should strive to perpetuate concerning 'desirable' consumption profiles.

The rest of the paper is organised as follows: Section 2 outlines the empirical methods. Section 3 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 estimated by comparing net changes in resource use attributable to changes in demand. Section 4 concludes the paper identifying implications and areas for future research.

2. Estimation method

In this section, we present a simple approach to calculate the resource intensity required to produce key food items. This approach recognises the influence of trade relationships that complicate the underlying conditions of food production. We outline the key methods used in our study, including Engel curve estimation, income elasticity and novel approaches to measure resource requirements.

The 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 ensures that the good will align with consumer preference in seeking utility maximisation. Therefore, the value of the good can be somewhat justified by the inputs 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. Hence, we start with categorising food by resource intensity. Household demand behaviour is modelled on the traditional demand frameworks of Engel curves and income elasticity estimation, and how they support analysis of household demand for food is also considered. Finally, the estimation method of additional resource needs attributable to changed food demand is derived to illustrate the tangible impacts that economic development has for resource use.

2.1 Categorising food by resource intensity

We offer a simple approach to the development of a resource intensive scale considering three resource inputs: land; water; and fossil fuel. Research that organises agricultural production by a comprehensive 'resource intensive' measure is not very common. The existing literature (Gerbens-Leens *et al.* 2003; Sainz 2003) focuses on estimating resource use in agriculture only from a fixed perspective, such as land use, which highlights the weakness of the methodology. This offers increased scope for developing calculations of agricultural resource input requirements with changed demand, as required for our research.

For our study, we consider 13 food items taken from IFLS data.[3] Analysing food demand patterns with respect to resource intensity requires the food items to be categorised with respect to resource input requirements in production. Three major agricultural resource inputs – fossil fuels, land and water – underpin organisation of the resources into their respective categories. Table 1 displays the food items corresponding to categories of low, moderate and high resource production requirements.

The organisation of the food items into the above categories draws on findings of agronomic research that estimates resource input requirements for fossil fuels, land and water. Appendix S1-I reports the full details of the estimated input requirements for individual food items. Table 2 shows the level of resource inputs across the three groups averaged for the 13 food items. 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 resource intensive relative to the low category.

We have assumed production technology differs between domestically produced foods and imported foods from industrial countries. This implies that different resource input requirements exist for equivalent food items (Pimentel and Pimentel 1979). FAO trade statistics and food balance sheet data over the decade 1997–2007 reported in Appendix S1-II show that Indonesia relies upon both domestic and international production sources in meeting food demand profiles, especially for moderate and high resource intensive food items.[4]

Resource requirements inclusive of both domestic and foreign (industrial) production systems have therefore been accounted for in our analysis. The resulting resource input figures reflect the combined impact of both domestic and imported food items and the underlying input requirements of the production system for all moderate and high resource intensive items based on availablity.[5] Where industrialised production estimates were not available, we have adjusted the available figures (downwards) to determine the final resource input for the category as reported in Appendix S1-XI where appropriate to reflect the additional efficiencies achieved through

[3] The reasons behind this selection are described in Section 3.

[4] Industrialised countries accounted for the majority (>50 per cent) of Indonesian food imports by value in 1997, 2000 and 2007. Australia and the United States are Indonesia's two largest import sources. In 2007, 30.4 per cent of the value of Indonesian food imports was sourced from these countries. Other major industrial exporters of food products to Indonesia are Canada, New Zealand, Malaysia, Singapore, the Netherlands, France, South Korea, Belgium, Germany and Japan.

[5] We assume that all low resource intensive food items are met by domestic production or by imports from an equivalent production system (and therefore resource requirements) from a neighbouring developing country.

Table 1 Food items categorised by resource intensity

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	

Table 2 Level of resource inputs required across three food categories†

Food category	Fossil fuel (MJ/kg)	Land (m^2/kg)	Water (kL/kg)	Average relative change ($\bar{\gamma}$)
Low	2.35	1.02	0.87	1.0
Moderate	8.08	1.51	1.98	1.4
High	26.73	12.60	22.49	15.5

Note: †See Appendix S1-II for detailed food item individual resource input requirements. Fossil fuels are measured in megajoules (MJ) = 10^6 J; land measured in square metres (m^2); water measured in kilolitres (kL) = 1,000 L.

industrialised production techniques. 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. Our results provide a basic treatment of resources used in the production of food both domestically and abroad (as satisfied through trade).[6]

It is important to note that we assume a one-to-one relationship between food prices and natural resource prices. In agricultural production, the dependence on natural resources is often insurmountable, technological progress is slow, and substitutability between inputs is limited. Given this, we argue that this relationship may hold, at least in the short to medium-term. However, in the long-term, it is likely to change, and our analysis does not take care of such long-run general equilibrium consequences.

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

[6] Providing a separate analysis that distinguishes between resource requirements attributable within Indonesia and other countries is something we leave for future work. Here, we aim to demonstrate the changing nature of demand in a developing country and its implications for resource requirements. Implicit to this is that food demand in an open economy (that allows for trade) will draw upon resources on a global scale.

2.2 Engel curve estimation

Engel curves are estimated for food items organised by both dietary and resource intensive means. Engel curves (Engel 1857) provide insight into how household expenditure decisions compared across or between a subset of commodities as income (expenditure) changes. 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. 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.

Conventional estimation of Engel curves is based on a parametric model (Working 1943; Leser 1963) modelled as:

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

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

The accurate estimation of the parametric approach depends upon specification of a functional form that reflects the underlying data distribution (Howe *et al.* 1979; Deaton 1985; Kneip 1994). In addition, endogeneity remains a notable concern. As total expenditure is often determined by expenditure shares of commodities themselves, this variable is commonly considered to be endogenous (Blundell *et al.* 1998). Furthermore, total expenditures may be mismeasured from expenditure surveys given the infrequent purchase of particular commodities (Meghir and Robin 1992). We use Lewbel's (2012) two-stage estimation approach, which controls for issues of mismeasurement and endogeneity of household expenditure. The triangular system for the relevant Engel curves is presented as:

$$Y_1 = \alpha_1 + \gamma_1 Y_2 + \mathbf{X}'\beta_1 + \varepsilon_1, \tag{2}$$

$$Y_2 = \alpha_2 + \mathbf{X}'\beta_2 + \varepsilon_2, \tag{3}$$

where the Y_1 is food category budget share, Y_2 is the log real total expenditure, and $\mathbf{X}'$ is a vector of exogenous regressors.

Typically, Y_1 is estimated by identifying instruments for Y_2 that satisfy the standard exclusion restrictions[7] if $\beta_1 \neq 0$. Lewbel (2012) proposes that instrument identification can be achieved independent of the exclusion

[7] 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.

restrictions, provided that there is a set of exogenous variables $\mathbf{Z}$ (equivalent to $\mathbf{X}'$) with heteroskedastic errors in $(\varepsilon_1, \varepsilon_2)$. The set of variables comprising $\mathbf{X}'$ and equivalently $\mathbf{Z}$ 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 that is regressed on the $\mathbf{Z}$ vector defined above and the vector of residuals ξ are obtained:

$$Y_2 = \alpha + \mathbf{Z}'\gamma + \xi. \tag{4}$$

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

$$\mathbf{X}_j = (\mathbf{Z}_j - \overline{\mathbf{Z}})'\xi, \tag{5}$$

where $\mathbf{Z}_j$ is the estimated mean-centred residual for the given exogenous variable, $\overline{\mathbf{Z}}$ is the centred mean of $\mathbf{Z}_j$, ξ is the vector of errors, and $\mathbf{X}_j$ is the estimated instrument.

Application of the Breusch–Pagan test of heteroskedasticity strongly rejects the null of homoskedasticity for the residuals, satisfying Lewbel's first-stage estimation condition for heteroskedastic errors. The instruments generated from Equations (4) and (5) 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.[8]

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

2.3 Income elasticity of demand

We estimate income elasticities for each resource intensive category, supplementing the Engel curve results. 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

[8] Emran and Hou (2013) also demonstrate the value of the approach in providing robust identification in the absence of the standard exclusion restrictions.

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:

$$\ln Q_{ijkty} = \alpha + \beta_1 \ln P_{ijkty} + \beta_2 \ln Y_{ijkty} + \beta X_{jt} + \beta Z_{ct} + \varepsilon_{ij}, \quad (6)$$

where $i = 1, 2, \ldots, 13$ (food item); $j = 1, 2, \ldots, n$ (household); $k = 1, 2, 3$ (resource intensive food category); $c = 1, 2, \ldots, 321$ (community); $t = 1997$, 2000, 2007 (survey year); $y = 1, 2, 3, 4$ (income quartile). P, Y, X and Z represent price, income, demographic, and community characteristics, respectively.

Elasticities are estimated for each food item i within a resource category k. Individual item elasticities are weighted by their expenditure share of the relevant category, before being aggregated in accordance with 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 are estimated with respect to income quartiles, by urban/rural locality and a pooled measure.

2.4 Additional resource requirements

The estimation of additional resource needs attributable to changed food demand is the final component of our study. 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 2.1, which is assumed to remain constant throughout the study period.[9] Both 'absolute' and 'relative' changes to resource requirements are considered.

2.4.1 Absolute requirements

Estimating absolute additional resource use is completed for the resource inputs. Four terms have been constructed to compare the amount of resources used to satisfy food demand through the study period:

[9] 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 improvements in technology and production efficiency, which can potentially reduce input requirements. The latter can be attributable to increased resource scarcity, which drives production to rely on increasingly marginal resources, impacting efficiency.

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.
$D_{2ir} = (Base_i Exp_{0i})$	Product of baseline resource and real expenditure growth.[10]	Resource level required to satisfy a share of consumption in 1997 allowing for real expenditure growth.
$D_{3ir} = (Base_i Exp_{1i})$	Product of baseline resource and real expenditure growth from 1997 to 2007 and change in budget share.[11]	Resource level to satisfy a share of consumption in 2007 allowing for real expenditure growth.

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

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; $c_{1i} = {}_{0i}$ as for 2007; Exp_{0i} = real expenditure growth between 1997 and 2007; and Exp_{1i} = product of Exp_{0i} and change in budget share between 1997 and 2007.

From the four terms listed above, three measures are constructed to estimate differences in resource inputs through demand changes. Each measure is interpreted as the additional resource input amount required to satisfy a given unit of an individual's consumption profile.

Measure 1 provides an estimate for the resource requirement disparity through a change in the consumption weight alone. Measure 2 compares the resource requirement accounting for real expenditure growth alone. Measure

[10] Refer Appendix S1-III. from 1997 to 2007.
[11] Refer Appendix S1-IV. from 1997 to 2007.

3 compares the resource requirement accounting for real expenditure growth and changes in demand.

2.4.2 Relative resource requirements

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

$$\gamma_{ir} = \frac{\alpha_{ir}}{\mathrm{low}_r}, \tag{7}$$

$$\overline{\gamma}_i = \frac{\sum_r \gamma_{ir}}{3}, \tag{8}$$

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; $\overline{\gamma_i}$ = average relative resource use across all inputs.

This measure calculates the relative resource use accounting for real expenditure growth and changes in the budget share from 1997 to 2007. We denote real expenditure growth by β_{0i} and real expenditure growth weighted by the change in budget share as β_{1i}. The difference between the product of average relative resource use ($\overline{\gamma_i}$) 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 from the change in demand. Aggregating these differences provides the net relative difference in resource use:

$$(\text{Relative difference}_i) = (\beta_{1i}\overline{\gamma}_i) - (\beta_{0i}\overline{\gamma}_i). \tag{9}$$

3. Data and empirical results

3.1 Data

We use the IFLS data, a longitudinal survey that collects a variety of socioeconomic and health indicators at the household and community level. Four survey rounds have been conducted in years 1993, 1997, 2000 and 2007 to date. Recontact rates have been maintained above 90 per cent between the rounds, and the survey represents approximately 83 per cent of the Indonesian population (Strauss *et al.* 2009). As the first IFLS round of expenditure methodologies is inconsistent with later rounds, IFLS1 (1993) has been omitted from the analysis.

While the latest round of data included in this study comes from 2007, the core factors driving household demand behaviour generally have remained comparable beyond the time period considered in our analysis.[12] Therefore, our findings still hold relevance for policy application.

The most relevant aspect of the IFLS for our study relates to household food expenditure and consumption data. The study records expenditure information (recall period of 1 week) for 38 individual food items. While a measure of consumption that is recorded in quantity terms (necessary in modelling food demand behaviour) is absent from the data set, the IFLS records food price information at the community level.[13] Only 13 food items recorded at the household level match with items recorded at the household level yet account for approximately 70 per cent of total food expenditure, which makes analysis relatively robust.

To ensure that 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 province level price is adopted. Consumption, expenditure and other demographic variables measured in time units were converted to annual terms to ensure consistency. As households were surveyed over a full year, any bias caused by seasonal availability of food is controlled for when scaling from weekly to yearly consumption behaviour given the staggered nature of the sampling time frame (Strauss *et al*. 2009).

In addition to food expenditure and prices, a variety of other IFLS demographic variables have been incorporated to control for the economic and noneconomic factors affecting food demand. A measure of household income was constructed from salary, farm business income, asset income outside business activity, nonlabour earnings, self-employment income and transfer income. The exhaustive list of all variables extracted from the IFLS for our analysis is listed in Appendix S1-V.

3.2 Descriptive statistics

Household demographics are presented in Table 3. The data cover 7,566 surveyed households in 1997, 10,256 in 2000 and 12,977 in 2007. Descriptive statistics highlight the impact of income and location (rural/urban) on key demographic variables. Economic development shows households exhibiting higher education outcomes, smaller family sizes, having a male household head and to located in an urban area. The significant income gap between the poorest and richest quartiles will be a major factor in determining food consumption.

[12] It is hypothesised that the shift in food demand patterns is primarily caused by sustained growth in disposable personal income, rapid urbanisation and improved literacy rates leading to higher female labour participation. The behaviour of these phenomena has remained comparable from 1997 to 2007 and post-2007 to present.

[13] Deaton and Zaidi (2002) argue that when quantity data are absent from consumption information, price data from the relevant community are the next preferable alternative for calculating consumption quantities. Incorporating price information with expenditure amounts allows for the quantity consumed per household to be estimated.

Table 3 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	30,799	7,700	7,699	12,936	17,863

3.3 Engel curves[14]

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. Appendix S1-VII shows the food items corresponding to their respective dietary food category, and S1-VIII and S1-IX report the elasticity coefficients for Lewbel's (2012) Engel curve estimation. 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 two-stage least square (TSLS) regression results show 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. Therefore, as household expenditure rises, less is spent on staple food items relative to animal products.

These results show that household behaviour is consistent with our expectation, confirming from a dietary perspective the empirical consensus linking economic development and food demand favouring affluent, westernised consumption patterns. Forthcoming results when analysed from a resource intensity perspective for Indonesia may also be appropriate for other developing countries, strengthening their significance.

The estimation of Engel curves for the three resource intensive food categories (Table 1) demonstrates the implications of economic development for resource use. The Lewbel (2012) technique, with the same vector of exogenous variables ($\mathbf{Z}$), is again used in estimation. The resource intensity TSLS regression results are presented in Appendix S1-IX. These results show that for a rising household expenditure, the proportion of expenditure on low resource intensive items falls at a greater rate when compared to moderate and high resource items.[15]

[14] Appendix S1-VI shows dietary and resource Engel curves (1997–2007), which omit outliers beyond 2 standard deviations from the mean.

[15] The abnormally small coefficient for the higher resource category in 2000 may be explained by the economic environment resulting from the Asian Financial Crisis.

These results show for rising expenditure that a household will allocate a greater share of expenditure towards high resource intensive items. This is confirmed through the magnitude of the expenditure change: 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 resource intensive items. Despite falling budget shares across each of the resource intensive (and dietary) categories consistent with Engel's law, the absolute amount of real expenditure still rises. These findings have profound implications: economic development, a key driver of household expenditure is associated with higher expenditure levels towards food items, which require more resources in their production. Notwithstanding the advantages of economic development, these results suggest that this phenomenon will also accelerate the demand for nonrenewable resources such as land, water and fossil fuel.

3.4 Elasticity

The log–log model outlined in Section 2.3 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 Appendix S1-X. For the aggregate sample, income elasticity rises with the corresponding level of resource intensive categories. The elasticity measures remain similar between the survey waves, dismissing any strong dynamic effects on Indonesian food demand patterns over the study period.

Our results show that income elasticity depends on the household location. 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 per cent increase in the quantity demanded for the high food resource group by a rural household compared to a 11.6 per cent increase from an urban household. These results support concepts of food demand being linked to regional development in Indonesia (Pangaribowo and Tsegai 2011). Nevertheless, in both rural and urban localities high resource intensive food items are associated with increased income elasticity.

Results by income quartile highlight 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's 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 display the highest income elasticity. This challenging result may be explained by the income level recorded across many of the poorest households as being zero or even negative.[16] This may implicate the integrity of elasticity estimation given

[16] There were 1,405 household in 1997; 1,154 in 2000; and 1,980 in 2007, where per capita annual income was equal to or less than zero. A negative income is plausible given that the income variable was constructed.

the significant presence of zero income entries, which would bias the OLS estimation. The wealthiest households' income elasticity is lower compared 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.

Increasing household affluence will generate an increasing tendency to spend additional income on food items that are more resource intensive. This effect is mitigated once the household falls into the highest income quartile, suggesting that income elasticity growth may reach saturation. 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.

3.5 Additional resource use

We now turn to the results, which describe the net effects of demand on per capita resource use in both absolute and relative terms. Table 4 reports the absolute per capita resource needs across the three inputs and estimate indicators developed in Section 2.4. Appendix S1-XI contains the input numbers for each estimate.

The results show that changes in food demand, which have been empirically established through Engel curve and income elasticity estimation, require increased resource inputs. All results are non-negative, aside from Estimate 1 for the moderate resource intensive category due to the fall in consumption share for this category from 1997 to 2007. Estimate 3 shows that on a per capita basis, changes in demand measured through consumption and budget shares accounting for real expenditure have increased fossil fuel (MJ's), land (m^2) and water (kL) resource inputs by 3.13, 1.24 and 2.1 units, respectively, to satisfy consumption relative to the base period.

We also consider the relative increase in additional resources from changing demand behaviours. Table 5 reports aggregate resource measures for the averaged relative resource input intensity between the three categories. The base case is inclusive of real expenditure growth over the study period. It is compared to a variable budget share which represents changed demand. The resulting terms are interpretable as relative resource units, rather than reference to a specific amount of resource input.

The results show the net effect of changed demand patterns leading to an outcome where the resource requirement is 8 per cent higher than the status quo. These effects are more than offset by the growth in demand for moderate and high resource intensive categories, with the aggregate value reflecting this.

It is assumed that growth in real food expenditure will translate to an increase in the amount of resources necessary to supplement production. The quantification in both absolute and relative terms demonstrates for the study period,

Table 4 Estimate results for additional resource use (absolute†)

	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

Note: †See Appendix S1-VII for detail into the absolute input requirements.

when controlling for changes in real expenditure, that demand patterns lead to an increased resource requirement on a per capita basis within Indonesia. We reiterate that this increase is attributable to resources both domestically and abroad determined through the respective production systems.

The results should be recognised in the context of the increase in Indonesia's population by some 34.1 million people over the study period. This effect compounds the impacts of rapid economic development, placing increasing demand on global resource inputs required in agricultural production to meet Indonesia's expanding food consumption profile. Our results are likely to reflect a similar trend in comparable Asian countries, highlighting the need for further empirical research. Understanding other developing countries' demand for resource intensive foods (particularly in Asia where the strongest levels of population growth are expected) will provide important evidence into the impacts that economic development brings upon natural resource use.

4. Conclusions and policy implications

This research presents an analysis of food demand patterns of Indonesian households from the perspective of resource requirements. Results from the Engel curve and income elasticity 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. We also quantified the additional resource inputs used as a result of changed demand patterns over the study period. After controlling for real expenditure growth, these results show that fossil fuel, land and water input requirements increased significantly.[17]

[17] The factors that drive the food demand pattern in Indonesia remain valid in post-2007 period. For example, between 1997 and 2007, GDP per person per annum averaged 1.4 per cent (excluding 1997 and 1998 as an outliers due to the impact of the Asian Financial Crisis, this figure rises to 3.6 per cent) while between 2008 and 2015, it was 4.2 per cent (Source: World Bank Data Bank: Indonesia http://data.worldbank.org/country/indonesia). Similarly, the rural–urban migration rate from 2010 to 2015 was 2.6 per cent compared to 4.6 per cent in our study period that covered the period from 1995 to 2005 (UNDESA 2012).

Table 5 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
Moderate	3.51	3.93	0.42
High	21.35	23.13	1.78
Aggregate	25.99	28.08	2.09

These results raise several key policy challenges regarding natural resource management. Our quantified association concerning economic development and increased natural resource use will motivate inquiry into the economic policies of demand management of natural resources, through changing food demand patterns. Implications of policies addressing supply and/or demand side approaches concerning the agricultural supply chain in the context of resource use should be explored. 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 given 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 in developing countries (Gerbens-Leenes *et al.* 2010).

This study provides the foundation to conduct similar empirical analysis for other developing countries. Future research should strengthen the consensus that economic development is associated with food demand patterns that are more resource intensive. By 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 may impact on food affordability, access and environmental degradation. The outcomes of economic development may well promote a future where food security is an inherently challenged panacea on account of food demand being increasingly resource intensive.

Few possible extensions of this study may include first, taking the quality of food consumed over the study period into account, a factor which affects dynamic food demand. Secondly, the analysis could be extended to the derived demand for atmospheric pollution including carbon emissions, viewing the capacity of the atmosphere to absorb emission as another natural resource.[18] A dynamic treatment of food prices and natural resource prices would also strengthen our findings given our assumed fixed relationship. Estimating the derived demand for resource requirements both for Indonesia and those countries that supplement the food balance sheet would enable these influences to be clearly articulated. Lastly, the

[18] We are grateful the referees for this suggestion.

accuracy of our method used to estimate the resource input intensity could be improved if an index that recognised factors such as resource price, environmental cost and productivity, for different production regions, were applied. An index which controls for heterogeneous regional effects relating to resource scarcity, input intensity and price may be a heroic ambition, considering the breadth of this measure.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Item I. Food items and individual resource inputs.
Item II. Value of agricultural trade (IDR '000).
Item III. Household real expenditure growth across resource categories.
Item IV. Household food budget shares for food.
Item V. IFLS variables in demand analysis.
Item VI. Engel curves – dietary and resource (1997–2007).
Item VII. Dietary food categories.
Item VIII. Engel expenditure share coefficients for dietary food categories.
Item IX. Engel expenditure share coefficients for resource intensive food categories.
Item X. Income elasticity (weighted).
Item XI. Input figures for absolute net resource use.