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Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise

Nadjia Mehraban [a], Amy Ickowitz [b,*]

[a] University of Goettingen, Goettingen, Germany
[b] Center for International Forestry Research, Bogor, Indonesia

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ABSTRACT

Despite great strides in reducing hunger over the last two decades, malnutrition remains a major challenge in Indonesia. High rates of child stunting coexist with high and increasing rates of overweight and obesity despite rapid economic growth and reductions in poverty over the last two decades. Part of this economic growth has been driven by a change in agricultural production systems from traditional farming techniques with farmers growing multiple crops to more intensified, specialized and commercialized farms. The objective of this study is to analyze how changes in the structure of agricultural production have affected diets in rural Indonesian households over time. We use three waves of a panel data set from the Indonesian Family Life Survey with a balanced sample of 2785 rural households covering the period between 2000 and 2015 to see how households' food choices have been changing over time in response to the changes in production systems.

We find positive relationships between production diversity and household dietary diversity as well as between market access and household dietary diversity. However, we see that there has been an overall decline in dietary diversity over time in the same households as their production diversity has declined. This decline in dietary diversity was mostly driven by the decreased consumption of nutritious food groups (fruits, vegetables, legumes, and fish). Although the magnitude of the association between dietary diversity and production diversity was relatively small, the association between household production and consumption of some of these important food groups was quite substantial. The overall impact of increased specialization in Indonesia during the period 2000–2015 on dietary quality appears to have been negative.

1. Introduction

Whether farmers are nutritionally better off from producing a diverse set of food crops or from specializing in crop production for sale and then purchasing food has been the subject of debate among researchers (Jones et al. 2014; Sibhatu et al. 2015; Hirvonen and Hoddinott 2016; Jones 2017a; Sibhatu and Qaim 2018; Gupta et al. 2020). This debate has important implications for national and international development policies; if greater specialization and commercialization also improves diet quality, then governments, donors, and international organizations can continue to focus their policies in this direction with the hope that they will bring higher incomes, more food, and better quality diets. However, if greater diversity of production results in better diet quality, then more nuanced policies might be necessary to support these multiple objectives. In this paper, we use panel data from rural Indonesia to investigate whether increases in farming specialization over a 15 year period were associated with better dietary quality as proxied by dietary diversity and nutrient-rich food group consumption.

Indonesia has experienced a substantial decrease in undernourishment over the last two decades (from 17% of the population in 1999 to 8.3% in 2017), however, other nutritional problems have not improved much and some have gotten worse. Child stunting and wasting have remained stubbornly high at 36% and 13.5% respectively (Global Nutrition Report 2020). Poor dietary quality is a widespread problem in Indonesia and micronutrient deficiencies in vitamin A, iron, and zinc are high (Shrimpton and Rokx 2013). There are some signs of a nutrition transition (Popkin and Gordon-Larsen 2004) characterized by increasing consumption of simple carbohydrates, fats, and animal foods and away from complex carbohydrates, fruits, legumes, and vegetables taking place in Indonesia (Vermeulen 2019). Overnutrition is increasingly a concern (Hanandita and Tampubolon 2015); overweight and obesity are on the rise, with 31% of adult women overweight and 9% obese (GNR

* Corresponding author.
E-mail address: a.ickowitz@cgiar.org (A. Ickowitz).

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2020) and rates of overweight and obesity among young children are increasing rapidly (GNR 2015; GNR 2020).

We use data from three waves of the Indonesian Family and Life Survey (IFLS) – 2000, 2007/8, and 2014/15 – covering about 83% of Indonesia's population. During this period, Indonesia went through rapid economic and social changes; annual income per capita[1] increased from $2144 in 2000 to $4285 in 2018 (World Bank, 2019), resulting in a change in Indonesia's status from a 'low income' to a 'upper middle income' country as classified by the World Bank. The landscapes of much of rural Indonesia were rapidly transforming over this period as well with increased production of cash crops, particularly of oil palm (Austin et al. 2019). Infrastructure and access to markets also improved with an increase in road density from 18.3 km per 100 sq km in 2000 to 26.1 km in 2011 (Knoema, 2020); an increase in electricity consumption of 108% between 2000 and 2014 (World Bank, 2019); an explosion of mobile phone use with an increase of 75 times the number of subscriptions between 2000 and 2015 (World Bank, 2019) and an increase in passenger air traffic of over 800% during that same period (World Bank, 2019). The increased specialization of Indonesian farmers accompanied by the rise in incomes over the last two decades, make Indonesia an excellent 'case study' for investigating how reductions in agricultural production diversity accompanied by economic development have affected diets over time.

1.1. Research hypothesis

There are several pathways through which agricultural specialization (i.e., a reduction in production diversity) and commercialization could affect household dietary diversity both positively and negatively: first, commercialization tends to be accompanied by improvements in infrastructure since producers need to connect to markets in order to sell their output for cash. This can improve access to different kinds of foods which would be expected to have a positive effect on dietary diversity. Second, higher incomes from more commercially oriented farms and plantations would enable people to purchase more kinds of foods from markets, again with a positive effect on dietary diversity. Third, replacement of diverse crops that were formerly produced and consumed with crops produced for sale, is likely to have a negative effect on dietary diversity. Fourth, loss of fallows and uncultivated lands with changes in production systems that normally accompany commercialization, could mean of loss of wild foods (wild meat, fruits, and leaves) normally collected in those areas (Powell et al., 2015; Broegaard et al., 2017) resulting in a negative effect on dietary diversity. While all of these pathways are possible in theory, the ultimate effects on diet will depend on how they interact and which effects dominate, if any.

Most studies that explore the determinants of dietary diversity use cross sectional data and then assume that the dietary responses of households that exhibit different degrees of specialization is equivalent to what would happen in the same household if it were to become more specialized. With panel data, we can observe these changes directly without the additional assumption. We can also reduce potential bias by using a fixed effects estimator which controls for unobserved household characteristics that do not change over time, but that could impact diets. The objective of this study is to understand how changes in the structure of agricultural production has affected diets in rural households in Indonesia over time as the country has experienced economic growth and development. We test the following hypotheses:

i. Reductions in production diversity associated with agricultural specialization are associated with reductions in household dietary diversity due to reductions in consumption of crops that are no longer produced by the household;
ii. Greater market access as a result of improvements in infrastructure is associated with increases in household dietary diversity through market purchases of diverse foods;
iii. The effects of changes in 'own production' and market access will differ for the different food groups that comprise the dietary diversity score; the impact of 'own production' is likely to be more important for some food groups and market access will likely be more important for others.

If both hypotheses i and ii are correct, they would each pull dietary diversity in a different direction with the overall effect depending on their relative strength. If hypothesis iii is correct, understanding which food groups are more responsive to own production and which to market use can help us to move beyond generalizations and ideological debates to design policies that are more effective at improving diets.

2. Data

We use household-level information from the Indonesian Family and Life Survey (IFLS), a longitudinal survey conducted by the RAND Corporation for Indonesia. It was first carried out in 1993–1994 and four more waves have followed including IFLS3 in 2000 (Strauss et al. 2004), IFLS4 in 2007–2008 (Strauss et al., 2009) and IFLS5 in 2014–2015 (Strauss et al. 2016). With 13 out of the initial 26 provinces (including the most populous ones), 83% of the Indonesian population is represented in the survey. For the present study, waves three to five, covering the period between 2000 and 2014/15 are used, as only these three waves contain specific information about farm production. The re-contact rate for the waves used here is over 90% from the first IFLS survey. We combine parts of the community level data for infrastructural development, which is available for the 130 IFLS original villages with the household level data.

Data from the first wave used for this study contain observations for 10,251 households. After excluding duplicates and incomplete observations (9), urban households (4,917) and non-farming households (2,113), the data provide a base of 3214 rural farmers in 2000. Combined data from 2000, 2007 and 2014/15 builds a balanced panel with 2785 households.

2.1. Dietary diversity and consumption of individual food groups

We use a count of food groups consumed by the household over the previous seven days to create a household dietary diversity score (henceforth HDDS) as a proxy for household diet quality. Although dietary diversity scores have only been validated as measures of nutrient adequacy and food security using 24 h recall periods for children and women (Verger et al., 2019), Fongar et al. (2019) show that 7-day household dietary diversity scores were significantly correlated with individual 24 h recall scores. Several other studies use the 7-day household recall to proxy for dietary quality (Arimond and Ruel 2004; Jones 2015; Sibhatu et al., 2015).

In order to measure household dietary diversity, we categorized reported food items into food groups, to align as closely as possible with the FAO guidelines[2] (Kennedy et al. 2013). Food groups included are: cereals, tubers, vegetables, fruits, meats, eggs, fish, legumes, dairy, oils and fats, sweets, spices and beverages. For further details on the food groups and the included food items, please refer to table A1 in the appendix.[3]

[1] GDP per capita in constant 2010 USD.

[2] For example, the IFLS did not have separate data on vitamin A rich vegetables, tubers and fruits, dark green leafy vegetables, or organ meat: we therefore could not construct a measure to align with the Women's Minimum Dietary Diversity Score.

[3] All prepared foods eaten outside and inside the house are aggregated into one group, however, this group is only used for descriptive purposes.

The composition of dietary diversity scores used in the literature varies: a 12 food group HDDS recommended by the FAO reflects the household's economic ability to access a diverse diet (Kennedy et al., 2013). Other researchers suggest using only nutrient relevant groups for a nutrient adjusted HDDS (Swindale and Bilinsky 2005) and excluding food groups that are not nutritious. In this study, we use different measures of household dietary diversity, namely 12 group, 10 group, and a 9 group measure - HDDS12 uses all food groups reported by IFLS; HDDS10 uses the 10 food groups which are more likely to have positive nutritional impact (spices-condiments-beverages and sweets are excluded), and the HDDS9 uses the food groups which we can align directly to our production data (this starts with the same food groups as HDDS10, but excludes fats and oils since IFLS did not collect production data for these foods). We use HDDS9 as our main outcome variable, while the other two measures are used in the supplementary analysis.

In addition to the analysis of dietary diversity, we also run a series of models exploring the factors associated with the consumption of the individual food groups that comprise the household dietary diversity scores. We use the recall data to generate dummy variables, indicating whether the household consumed each food group in the past seven days or not. Since we are most interested in the impact of 'own production' on consumption, we exclude sweets and eggs which are rarely produced at the household level in Indonesia.

2.2. Production diversity

We use a count of crops and livestock produced by the household as a measure of production diversity. While some studies only include crops, we also include livestock since it can be a source of animal source foods such as milk and meat. We use information from two sections of the survey to create this index: farm business and household consumption. In the farm business module, households are asked for information on production of crops and livestock in the last 12 months. However, the food groups covered in this section are limited. In the consumption module, households are also asked how much they consumed out of their own production for each food item. When they report a positive amount, we assume that to mean that they produced foods in that food group and use this information to expand the food groups included in a wider production diversity index. We generate three production diversity indices: PD9, PD10, and PD12 which use the same food groups as are used in our dietary diversity indicators (Berti 2015). PD9 uses only the data from the production module and uses the same food groups as HDDS9. The other two production diversity indices also include information from the consumption module as described and are used in supplementary analysis. In addition, we generate dummy variables indicating whether or not the household has produced foods in each food group for the second part of our analysis.

2.3. Market access

The second key explanatory variable of interest is 'market access', which we proxy by actual reliance on markets for consumption at the village level. Commonly used market measures are self-reported distance to nearest markets, existence of markets in the village or town (Sibhatu et al. 2015), nearest roads, and ownership of vehicles (Snapp and Fisher 2014). Jones (2017b) proportion of harvest sold to proxy for market access at the household level. We use a similar measure for market access but focus on the consumption side – the proportion of foods purchased out of total food consumption during the past seven days. However, because this measure could potentially suffer from endogeneity bias at the household level,[4] we average this measure across each community and use this average which we call '*community market reliance*' as a proxy for market access. In addition to our main market measure, we include distance to the nearest market from the village, as a robustness check since this measure is more commonly used in the literature.

[4] For example, there may be omitted variables such as having a well-informed person in the household who understands the value of a diverse diet, but also is well informed about market opportunities.

2.4. Other control variables

We control for socio-economic factors, such as education, age, sex and religion of the household head. Education can affect knowledge about healthy diets and thus is expected to increase dietary diversity. We use dummy variables for completion of primary, secondary or higher education of the household head. We note that female decision maker's education is potentially more important for household diets since women are more often responsible for purchasing and preparing food within households (Bhagowalia et al., 2012; Malapit and Quisumbing 2015). However, due to a large number of missing observations, we use the information of the household head instead, as there is evidence of positive correlation between husbands' and wives' educational attainment due to positive assortative matching in marriages based on education (Breierova and Duflo 2004).

Women have been shown to play an important role in improving the diets of their families (Amugsi et al., 2016; Chiputwa and Qaim 2016; Bhagowalia et al., 2012; Malapit and Quisumbing 2015), hence we control for female headed households. The age of household head is included since age may shape taste and preference for food (Westenhoefer 2005). And as 87% of Indonesia is Muslim and Muslims have religious dietary restrictions, we add a dummy for Muslim household heads. Total household size might affect dietary quality as well since more people may be reflected in more diverse preferences as well as more diverse activities resulting in different types of production and processing.

We control for the household's economic status with an asset and housing quality-based wealth index. We use Multiple Correspondence Analysis (MCA) to represent information on ownership of many assets and living conditions in a single index which we use to proxy for household wealth (Greenacre and Blasius 2006). We include: ownership of vehicles, TV, type of cooking stove (gas, electric, kerosene), own toilet, usage of piped or bottled drinking water, type of outer walls (bricks or cement), roof material (concrete, wood, metal), floor material (ceramic, marble, stone, tiles, cement or bricks). These assets and measures of living conditions are commonly used in the literature to reflect socio-economic well-being (Filmer and Pritchet, 2001). We categorized the highest tertile as *rich* and the lowest one as *poor*. The *middle* class is our comparison group. We include a variable for off-farm income generated by the household and total landholding. Some of the initially rural households moved to urban areas over time and since diets may differ in urban compared to rural areas, we add a dummy variable taking the value 1 if the household resides in a rural area.

We include dummies for the year of the survey to control for year-specific effects such as the state of the economy or weather patterns. In order to control for seasonality, which varies across Indonesia depending on the respective island, we include dummy variables for the month of interview.

3. Methods

We use a Poisson fixed effects model on a balanced panel to analyze the association between dietary diversity and production diversity and market access of the households over time. An advantage of a fixed effects regression is that unobserved characteristics of a household that do not change over time and might affect its dietary behaviour do not bias results. Thus such things that are difficult to measure and include in a model such as cultural norms, individual tastes and preferences for certain diets, knowledge about dietary decisions (that do not change over time) are all potentially important omitted variables which could bias estimates in a cross-sectional model, but do not present a problem in a fixed effects panel model.[5]

Since the dependent variable is a count of food groups, we use a Poisson fixed-effects model:

$$HDDS_{it} = \beta_1 PD_{it} + +\beta_2{}' \boldsymbol{X}_{it} + \beta_3{}' \boldsymbol{M}_{jt} + \beta_4{}' \boldsymbol{S}_{it} + \beta_5 yr2007 + \beta_6 yr2014 + u_{it} \quad (1)$$

where the dependent variable $HDDS_{it}$, represents the dietary diversity score of household i at time t; PD_{it} is the production diversity score of household i at time t; $\boldsymbol{X}_{it}$ is a vector of all potentially time-varying household characteristics such as gender, age, religion, education level of household head, household size, as well as information on whether the household resides in a rural area, has non-farm income, and size of landholding; $\boldsymbol{M}_j$ is a measure of market access (measured by average village market reliance and distance to nearest market) for village j; $\boldsymbol{S}_{it}$ controls for seasonality by including the interview month, and u_{it} is a random error term. We run the model for the different dietary diversity and production diversity scores described above.

Next, we run a set of random effects probit regressions for consumption of each food group on 'own production' of the same food groups and the controls used above. These regressions take the form:

$$\Pr(C_{git} = 1) = \theta_1 P_{git} + \theta_2' \boldsymbol{X}_{it} + \theta_3{}' \boldsymbol{M}_{jt} + \theta_4{}' \boldsymbol{S}_{it} + \theta_5 yr2007 + \theta_6 yr2014 + \mu_{it} \quad (2)$$

where C indicates whether household i consumed from food group g at time t; P indicates whether or not household i produced foods from food group g at time t. Vectors $\boldsymbol{M}$ and $\boldsymbol{X}$ and $\boldsymbol{S}$ contain the same control variables as in eq. (2) and μ_{it} is a random error term.

4. Results

The descriptive data presented in Table 1 show that between 2000 and 2015, production diversity in rural Indonesia declined. During this period, community market reliance did not change significantly. However, income in the sample increased over this period as did the proportion of the sample that were considered to be 'rich' based on an asset index and there was a decline in the proportion of the 'poor'. Despite these signs of economic development, average dietary diversity declined.

Table 2 presents the results of the panel fixed-effects regressions for each of the dietary diversity scores as incident rate ratios (irr) (since the poisson model is non-linear, the results are easier to interpret as rate ratios in response to a one unit change in the predictor). We see a positive and statistically significant association between household dietary diversity and production diversity; increasing production diversity by one food group is associated with a change in household dietary diversity of between 4.9% and 5.8% depending on the market access variables and other co-variates included in the model. As a robustness check, we run the regressions using HDDS10 and HDDS12 as outcomes and report the results in Table S2 in the online appendix. These results are qualitatively the same, but slightly smaller.

There is a significant and positive association between our preferred measure of market access - *community market reliance* with HDDS. This implies that households living in communities which are more integrated into market systems, tend to have access to more diverse diets controlling for other factors. However, the effect is quite small: an increase of 1% in *community market reliance* is associated with an increase of 0.02% in the household dietary diversity score. Market access proxied by the distance to the nearest market shows no effect.

Fig. 1 shows the mean values of consumption and production of each

Table 1
Descriptive statistics.

	(1)	(2)	(3)	(4)
	2000	2007	2014	Δ 2000–2014
HDDS9	6.60 (1.59)	6.62 (1.61)	6.51 (1.81)	−0.095* (0.046)
PD9	3.31 (1.54)	2.89 (1.65)	2.76 (1.71)	−0.56*** (0.044)
Cultivates cash crop (=1)	0.33 (0.47)	0.27 (0.44)	0.28 (0.45)	−0.049*** (0.012)
Landholding (ha)	1.14 (2.84)	0.67 (1.73)	0.68 (2.16)	−0.46*** (0.070)
Wealth Index: Poor (=1)	0.51 (0.50)	0.33 (0.47)	0.15 (0.36)	−0.36*** (0.012)
Wealth Index: Rich (=1)	0.16 (0.37)	0.28 (0.45)	0.56 (0.50)	0.40*** (0.012)
Annual real income (IDR/AE)	1628.7 (2370.8)	2565.6 (5580.6)	3359.5 (6696.2)	1730.8*** (134.6)
Annual real non-farm income (IDR/AE)	1592.7 (2345.1)	2565.6 (5580.6)	3348.4 (6684.6)	1755.7*** (134.2)
Annual real expenditures in (IDR/AE)	2065.2 (2111.9)	3603.4 (24000.7)	3752.0 (6429.8)	1686.8*** (128.3)
Community market reliance (%)	74.7 (21.2)	77.2 (21.8)	75.3 (22.4)	0.67 (0.58)
Rural area (=1)	1 (0)	0.91 (0.28)	0.82 (0.39)	−0.18*** (0.0073)
Nearest market (km)	4.10 (3.39)	5.25 (6.38)	4.51 (4.02)	0.42** (0.13)
Household size	4.40 (1.86)	4.01 (1.75)	3.78 (1.77)	−0.62*** (0.049)
HH has primary education (=1)	0.60 (0.49)	0.58 (0.49)	0.54 (0.50)	−0.063*** (0.013)
HH has secondary education (=1)	0.19 (0.39)	0.22 (0.42)	0.27 (0.44)	0.076*** (0.011)
HH has higher education (=1)	0.032 (0.18)	0.041 (0.20)	0.051 (0.22)	0.019*** (0.0053)
Female HH (=1)	0.12 (0.32)	0.16 (0.37)	0.19 (0.39)	0.069*** (0.0096)
Muslim HH (=1)	0.88 (0.32)	0.88 (0.32)	0.88 (0.32)	0.0025 (0.0086)
HH is married (=1)	0.88 (0.33)	0.83 (0.37)	0.79 (0.41)	−0.087*** (0.0099)
Observations	2785	2785	2785	5570

Notes: Mean values are shown with standard deviation (sd) in columns (1), (2) and (3). Column (4) shows the coefficients with standard error (se) in parenthesis from a simple *t*-test, comparing the means in 2000 to 2014/15. Income and expenditure values are constant to 2000. AE = Adult Equivalent. IDR = Local currency. HH= Household head. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

of the individual food groups in 2000 and 2014/15.

We see that household consumption of fruits, vegetables, legumes, tubers, cereals, fish, and tubers all declined over that period. Household production of all of these food groups (except for fish), also declined over that same period. By contrast, consumption of meat, eggs, and dairy all increased as did their production. Consumption of prepared foods eaten inside and outside the house increased over the period. This decline in consumption of plant-based foods, increases in consumption of animal foods, and increases in prepared foods are very typical of a nutrition transition (Popkin and Gordon-Larsen 2004) with the exception of declines in sweets.[6]

Table 3 presents the results of probit random-effects regressions as described in equation (2) for consumption of eight of the food groups. Since we are particularly interested in the impact of 'own production'

[5] A Hausman test failed to reject that a fixed effects model is appropriate for the dietary diversity poisson model.

[6] We suspect that this does not reflect an actual decline in sugar consumed, but instead the data that we used to construct the food group (sugar and soft drinks only) since detailed data on much of the packaged foods that contain sugar were not included in the survey.

Table 2
Factors associated with household dietary diversity.

	(1) HDDS9	(2) HDDS9	(3) HDDS9	(4) HDDS9
PD9	1.058***	1.058***	1.057***	1.049***
	(0.003)	(0.003)	(0.003)	(0.003)
Community market reliance (%)	1.002***	1.002***	1.002***	
	(0.000)	(0.000)	(0.000)	
Annual real non-farm income (IDR/AE)			1.007***	
			(0.002)	
Nearest market (km)				−1.000
				(0.001)
Wealth Index: Poor (=1)	−0.963***	−0.963***	−0.964***	−0.962***
	(0.009)	(0.009)	(0.008)	(0.013)
Wealth Index: Rich (=1)	1.032***	1.032***	1.029***	1.058***
	(0.008)	(0.008)	(0.008)	(0.011)
Landholding (ha)	−1.000	−1.000	−1.000	−1.000
	(0.002)	(0.002)	(0.002)	(0.002)
Household size	1.020***	1.020***	1.020***	1.022***
	(0.002)	(0.002)	(0.002)	(0.003)
Cultivates cash crop (=1)		1.002		
		(0.008)		
HH is married (=1)	1.104***	1.104***	1.107***	1.137***
	(0.020)	(0.020)	(0.020)	(0.029)
Muslim HH (=1)	1.052	1.052	1.059	1.104
	(0.057)	(0.057)	(0.057)	(0.083)
Female HH (=1)	1.074***	1.075***	1.085***	1.113***
	(0.017)	(0.017)	(0.019)	(0.028)
Age HH (Yrs)	−1.000	−1.000	−1.000	−1.000
	(0.000)	(0.000)	(0.000)	(0.000)
HH has primary education (=1)	1.015	1.015	1.015	1.026
	(0.014)	(0.014)	(0.014)	(0.020)
HH has secondary education (=1)	1.005	1.005	1.005	1.005
	(0.018)	(0.018)	(0.018)	(0.025)
HH has higher education (=1)	1.031	1.031	1.024	1.028
	(0.026)	(0.026)	(0.026)	(0.036)
Rural area (=1)	−0.978*	−0.978*	−0.981	−0.980
	(0.012)	(0.012)	(0.012)	(0.018)
Survey year 2007	1.038***	1.038***	1.036***	1.056***
	(0.014)	(0.014)	(0.014)	(0.020)
Survey year 2014	1.004	1.004	1.005	1.004
	(0.012)	(0.012)	(0.012)	(0.018)
Month dummies	YES	YES	YES	YES
Observations	7932	7932	7932	4335

Notes: Results from Poisson fixed-effects regressions with HDDS9 as outcome variable. Incidence rate ratios are shown with robust and clustered (at household level) standard errors in parentheses. Income variable is used in natural log. AE = Adult Equivalent. IDR = Local currency. HH= Household head. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

we focus on the eight food groups which are produced by households in more than marginal quantities in Indonesia.[7] We see that 'own production' is positive and statistically significant for all of the food groups – the probability of each food group being consumed by the household increases when the household produces it, but the magnitude of this relationship varies widely. The range of 'own production' effects for the different food groups is quite large from an effect of 66 percentage points for dairy to only 3 percentage points for cereals. Market access as measured by *community market reliance* also shows a positive and significant association with the consumption of all food groups: an increase of 1% in market access is associated with an increase of the probability of consuming each of the food groups by 1–2 percentage points.

5. Discussion

The results from the analysis provide support to all three hypotheses that we set out to test in this study. We find that in the panel sample of households, production diversity has a very strong positive association with household dietary diversity and market access is also positively associated with household dietary diversity. Both effects are relatively small. When looking at the individual food groups, the impact of own production on consumption varies widely with large effects for some food groups and negligible effects for others.

Over time, this sample of Indonesian households has experienced increased agricultural specialization, higher incomes, and lower household dietary diversity. Thus it appears that while markets did enable households to increase their household dietary diversity, this was not enough to outweigh the dietary diversity that was lost from more diverse 'own production'. Three recent studies that review the past literature on production diversity and dietary diversity (Jones 2017a; Sibhatu and Qaim 2018; Ruel et al. 2018) reach a similar conclusion – most studies find a positive and statistically significant association between production and dietary diversity, but with small effect sizes. Most of the previous literature used cross-sectional data (Sibhatu and Qaim 2018), but we identified a few that used panel data: Linderhof et al. (2016) used three waves of the LSMS-ISA data for Uganda, to analyze the effect of plot level production diversity on household dietary diversity and calorie consumption. They found a positive impact of production diversity on both outcome variables. Parvathi (2017) analyzed this relationship with a two year panel dataset from Lao and found small but positive effects of farm production diversity and market access on dietary diversity. Islam et al. (2018) used a two-round panel from Bangladesh and found a positive, but small association between various measures of production diversity and dietary diversity. Using panel data from Tanzania, Chegere and Stage (2020) also found that agricultural production diversity had a positive and statistically significant, but small effect on dietary diversity. They also found, however, that market access had no significant effect on household dietary diversity.

We find a bigger effect size when using HDDS9 compared with HDDS10 and HDDS12 (see SI). One interpretation of this finding is that the relationship between own production and diet quality is strongest for 'healthier' foods. Sibhatu et al. (2015) show a similar pattern with larger effects in their model that uses only healthy food groups. HDDS12 is a measure of 'access to food security' (Hoddinot and Yohannes 2002) and is supposed to be an indicator of the socio-economic status of a household. Thus it is surprising to see that it declined as assets (and income) increased.

The variables used to measure market access did not show greater access over the period (see Table 1). While community market reliance increased slightly over the period, the increase was not statistically significant. And the variable often used in other studies to indicate market access – distance to nearest market – actually increased. We hypothesize that this may be because respondents interpreted the question to mean 'wet markets' or weekly markets, as opposed to shops and mini-markets, which is why we think that this measure is not ideal for capturing market access. Vermeulen et al. (2019) report that Indonesia has been relatively slow in developing its food retail sector compared to other countries with similar income levels and compared to the rest of Asia.

While the size of the association between production diversity and dietary diversity in the sample is relatively small, the magnitude of the association between own production and probability of consuming several nutrient-rich food groups is quite substantial. Focusing on fruits for example, the results imply that the probability that a household consumes fruits increases by 32.5 percentage points if it produces its own fruit. This result is of particular importance given that fruit is one of the most-nutrient rich food groups with important positive health effects (Afshin et al., 2019) and fruits are under-consumed in Indonesia – with Indonesian consuming less than half of the recommended amounts

[7] These are the same food groups as in HDDS9, except for eggs. Only 2.3% of the sample owned chickens.

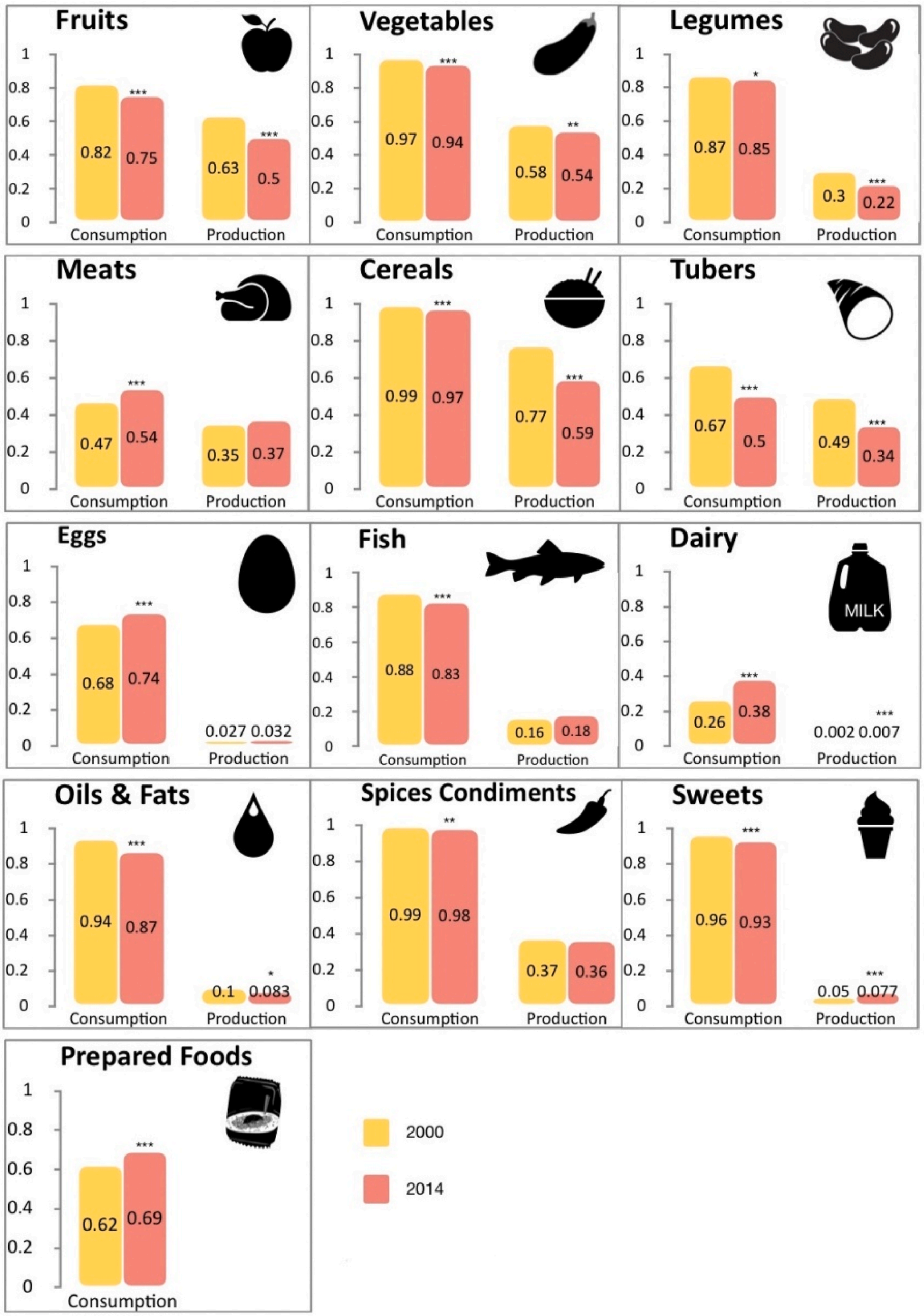

Fig. 1. Consumption and production of each food group in 2000 and 2014/15.

(Vermeulen et al., 2019).

This study has several limitations. First, the IFLS surveys were not designed as dietary surveys, but to look primarily at income and expenditures. This makes the data less than ideal for investigating dietary intake. However, despite the fact they are not able to tell us about individual dietary intake, they still have useful information that we exploit to tell us about overall patterns of food group consumption. They also have the advantages of being close to nationally representative and having repeated observations for the same households over time – two features which are rare to find in dietary surveys in LMICs. Second, the consumption data that we use are from a 7-day recall period instead of 24-h recall. While the 7-day recall period has the advantage of better capturing a household's food consumption pattern compared with a 24-h recall, it is more prone to recall bias as people have a more difficult

Table 3
Probability of consumption of each food group.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Vegetables	Legumes	Fruits	Meats	Fish	Tubers	Dairy	Cereals
Production of food group (=1)	0.109*** (0.008)	0.115*** (0.010)	0.325*** (0.007)	0.188*** (0.011)	0.241*** (0.018)	0.441*** (0.007)	0.670*** (0.122)	0.030*** (0.004)
Community market reliance (%)	0.001*** (0.000)	0.002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.000*** (0.000)
Wealth Index: Poor (=1)	−0.010* (0.005)	−0.060*** (0.009)	−0.046*** (0.010)	−0.097*** (0.013)	0.009 (0.009)	−0.016 (0.012)	−0.113*** (0.013)	−0.002 (0.004)
Wealth Index: Rich (=1)	0.004 (0.006)	0.010 (0.010)	0.069*** (0.010)	0.134*** (0.014)	0.030*** (0.010)	0.049*** (0.012)	0.062*** (0.013)	0.001 (0.004)
Annual real non-farm income (IDR/AE)	0.003*** (0.001)	0.002 (0.002)	0.008*** (0.002)	0.014*** (0.003)	0.008*** (0.002)	0.005** (0.002)	0.011*** (0.002)	0.001 (0.001)
Rural area (=1)	0.003 (0.007)	−0.030** (0.015)	−0.025* (0.014)	−0.028 (0.020)	0.053*** (0.013)	−0.071*** (0.017)	−0.030* (0.018)	−0.003 (0.005)
Landholding (ha)	−0.001* (0.001)	−0.003** (0.001)	−0.000 (0.002)	0.004* (0.002)	0.010*** (0.003)	0.000 (0.002)	0.003 (0.002)	−0.000 (0.001)
Household size	0.011*** (0.002)	0.012*** (0.002)	0.004 (0.002)	0.005 (0.003)	0.021*** (0.002)	0.018*** (0.003)	0.025*** (0.003)	0.005*** (0.001)
HH is married (=1)	0.039*** (0.007)	0.088*** (0.014)	0.066*** (0.015)	0.079*** (0.022)	0.062*** (0.014)	0.049** (0.019)	0.062*** (0.021)	0.020*** (0.005)
HH is muslim (=1)	0.002 (0.008)	0.142*** (0.011)	0.018 (0.013)	0.031 (0.019)	−0.007 (0.013)	0.077*** (0.017)	0.043** (0.017)	0.013*** (0.004)
HH is female (=1)	0.028*** (0.007)	0.081*** (0.015)	0.057*** (0.016)	0.096*** (0.022)	0.054*** (0.015)	0.057*** (0.020)	0.087*** (0.021)	0.017*** (0.005)
Age HH (Yrs)	−0.000 (0.000)	0.001* (0.000)	−0.000 (0.000)	0.001*** (0.000)	−0.001*** (0.000)	0.002*** (0.000)	0.000 (0.000)	−0.000** (0.000)
HH has primary education (=1)	0.000 (0.006)	0.019* (0.011)	0.003 (0.012)	0.062*** (0.017)	−0.008 (0.012)	0.047*** (0.015)	0.062*** (0.017)	−0.001 (0.004)
HH has secondary education (=1)	0.002 (0.008)	0.018 (0.014)	0.029* (0.015)	0.119*** (0.021)	−0.025* (0.015)	0.062*** (0.019)	0.131*** (0.020)	−0.011** (0.005)
HH has higher education (=1)	0.015 (0.014)	0.020 (0.023)	0.113*** (0.029)	0.236*** (0.035)	−0.041* (0.023)	0.082*** (0.029)	0.176*** (0.030)	−0.021*** (0.008)
Survey year 2007 (=1)	−0.009 (0.010)	0.029* (0.017)	−0.004 (0.018)	0.075*** (0.024)	−0.039** (0.017)	−0.042* (0.022)	0.058** (0.023)	0.021*** (0.007)
Survey year 2014 (=1)	−0.027*** (0.009)	−0.027* (0.015)	−0.068*** (0.016)	−0.003 (0.021)	−0.039*** (0.014)	−0.121*** (0.019)	0.053*** (0.020)	0.013** (0.006)
Month dummies	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7932	7932	7932	7932	7932	7932	7932	7932

Notes: Results from Probit random-effects models using consumption of individual food groups as outcome variable are presented. Average marginal effects are shown with standard errors in parenthesis. Income variable is used in natural log. AE = Adult Equivalent. IDR = Local currency. HH= Household head. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

time recalling foods that they ate in the more distant past (Coates et al., 2012). Second, we use household level data on consumption instead of individual level data. This is not ideal for consumption information because normally there is one respondent per household and s/he is unlikely to be able to recall all of the foods consumed by everyone in their household in the preceding week. This could present a problem for the results if the respondent systematically over-reports or under-reports consumption for some members of the household who more/less frequently consume out of own production. Third, dietary diversity scores have only been validated as measures of nutrient adequacy using 24 h individual level recall data from children under two and for adult women (Working Group on Infant and Young Children Feeding Indicators 2006; Arimond et al., 2004). Fongar et al. (2019), however, conclude that 7 day household level recalls were acceptable proxies for individual level dietary quality in a sample of rural households in Kenya and that therefore "household-level data can be used to calculate valid proxies of the diets of children and male and female adults when individual-level data are not available". Fourth, while using household fixed-effects in the dietary diversity regressions is able to control for time invariant unobserved heterogeneity, omitted variables that change over time could still potentially bias results. And finally, since a Hausman test rejects the use of fixed effects methods for the food group consumption regressions, there is still a possibility of bias from both time-invariant omitted household level characteristics as well as those that change over time.

6. Conclusion

Indonesia, like many other emerging and developing countries, is facing several nutritional challenges – declining, but still existing, undernourishment, widespread micronutrient deficiencies, and a high and rising rate of overweight and obesity. Poor diets are one important contributing factor to these nutritional challenges. Recent research has used dietary diversity as a measure of diet quality and has debated the role of agricultural specialization in changing rural diets. Agricultural specialization seems to have mixed effects on dietary diversity – a loss of as a result of decreases in the number of food groups consumed from 'own production' and a gain in diversity as a result of increases in food groups consumed from market purchases enabled by higher incomes. Here we try to answer the question of which of these two effects has dominated in rural Indonesia? In the panel of Indonesian households studied here, the increase in food group consumption from the use of markets did not compensate for the decline in food group consumption from 'own production'. We follow up with an investigation into the food groups that are responsible for this decline and estimate how much changes in own production of these food groups was associated with the declines in their consumption.

The overall impact of increased specialization on household dietary diversity for rural households in Indonesia appears to have been negative; households did not fully replace the food groups that they no longer consumed out of their own production through market purchases**.** What is especially concerning, is that the food groups that have been declining are amongst the most nutrient-rich and protective against non-communicable diseases, i.e., fruits, vegetables, legumes, and fish (Afshin et al., 2019). While some of the food groups that have increased over this period are also nutrient-rich, i.e. dairy, eggs, and meats, and can be important components of healthy diets, they also pose future risks for a population that is experiencing a rapid increase in cardiovascular diseases and overweight and obesity (Vermeulen et al., 2019).

In the end, it is not whether dietary diversity is associated more strongly with markets or 'own production' that matters most in order to understand how to nudge societies towards healthier diets. Dietary diversity is, after all, a summary measure that has its uses as an overall indicator, but in order to understand which food groups people are consuming and how to influence them, we have to go deeper. Particularly in the context of the nutrition transition, it is important to see the factors most strongly associated with the increase and decline of the different food groups. Here the picture is quite clear: As people are growing fewer fruits, vegetables, and legumes, they are also eating less of these nutrient-rich foods; conversely, as people's incomes are rising they are increasingly purchasing dairy, eggs, and meat. Thus there appear to be nutritional gains and losses. The policy challenge is how to maintain the improvements in dietary quality that accompany increased specialization and rising incomes, while doing something to minimize the dietary 'losses' that seem to arise from declining production diversity.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gfs.2021.100502.

Appendix

Table A1
Food groups and included items in dietary diversity indicators

Food Group	Included items in HDDS	Included items in PD	Food Group	Included items in HDDS	Included items in PD
Cereals	staples/rice, corn, sago/flour, noodles, rice noodles, macaroni, shrimp - chips, other chips, and the like	rice, corn, own production of cereals	Legumes (Legumes, Nuts, Seeds)	tofu, tempe, beans, peanuts	groundnuts, cashews and other nuts, soybean, own production of legumes
Tubers	cassava, other staples like potatoes, sweet potatoes, yam	cassava, other tubers, own production of tubers	Dairy	fresh milk, canned milk, powdered milk and the like	Cattle, own production of dairy
Vegetables	kangkung, cucumber, spinach, mustard greens, tomatoes, cabbage, katuk, green beans, string beans and the like.	red onion, other vegetables, own production of vegetables	Oils and Fats	butter, cooking oil like coconut/peanut/corn/palm and the like	Own production of oils and fats
Fruits	fruits like papaya, mango, banana etc	coconut, bananas, other fruits, own production of fruits	Sweets	granulated sugar, brown sugar, cocoa drink, soft drinks,/cookies, breads, crackers	Sugarcane, own production of sweets
Meats	beef, mutton, water buffalo and the like, chicken	chickens, pigs, goats, cattle, own production of meats	Spices (Spices, Condiments, Beverages)	spices like shallot, garlic, chili, coriander, candle nuts, MSG and the like, shrimp paste, salt, sauce, soy sauce, tea, coffee, Alcoholic beverages	chili, spice, coffee, own production of spices
Eggs	bird/chicken eggs	Chickens, own production of eggs	Fish	fresh fish/seafood, salted/smoked fish	Fish, own production of fish
Prepared foods	Prepared foods eaten outside and inside the house				

Notes: This table shows the food items asked in the questionnaires and how we grouped them into each food group comparable to the FAO guidelines.

Table A 2
Components of dietary and production diversity measures

Production Diversity Measures		Household Dietary Diversity Measures	
PD12	Cereals, tubers, vegetables, fruits, meat, eggs, fish, legumes, dairy, oils and fats, spices and condiments, sugar	HDDS12	Cereals, tubers, vegetables, fruits, meats, eggs, fish, legumes, dairy, oils and fats, spices-condiments and beverages, sweets
PD10	Cereals, tubers, vegetables, fruits, meat, eggs, fish, legumes, dairy, oils and fats	HDDS10	Cereals, tubers, vegetables, fruits, meats, eggs, fish, legumes, dairy, oils and fats
PD9	Cereals, tubers, vegetables, fruits, meat, eggs, fish, legumes, dairy	HDDS9	cereals, tubers, vegetables, fruits, meats, eggs, fish, legumes, dairy

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