What Drives Diversification of National Food Supplies?
A Cross-Country Analysis

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ABSTRACT

Although the diversification of national food supplies (DFS) is a necessary (but not sufficient) condition for the diversification of diets and for reductions in undernutrition in poor countries, little previous research has analyzed how DFS varies across countries and regions, how rapidly it has changed over time, and what economic, social, and agroecological factors may be driving these observed patterns and trends in DFS. The study addresses those questions through a cross-country analysis. We first review economic theory and evidence on the diversification of production and diets in developing countries, particularly the importance of economic growth and other structural transformation processes, as well as the scope for agroecological factors to shape consumption outcomes in the presence of market imperfections, such as high transport costs. We then construct and analyze a rich cross-country dataset linking a simple DFS indicator—the share of calories supplied by nonstaple foods—with a wide range of economic, social, infrastructural, and agroecological indicators. Descriptive evidence and regression analyses show that several indicators of structural transformation (economic growth, urbanization, and demographic change) are strong predictors of DFS within countries. However, the results also suggest that time-invariant agroecological factors are significantly associated with DFS, such that some countries have exceptionally low or high DFS relative to their level of economic development. We discuss the implications of these findings for food and nutrition strategies, particularly the challenge of accelerating dietary diversification in the absence of sustained and very rapid economic growth and structural transformation, especially in countries where agroecological conditions additionally hinder access to a more diverse food basket.

Keywords: dietary diversity; diversification of food supplies; nutrition; food systems; economic transformation
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1. INTRODUCTION

The widely used framework emphasizes that nutrition outcomes are the product of both food and nonfood factors (UNICEF 1990). However, for many economists and food security experts “food” in a nutritional context has often been directly equated to calories, with countless economic studies analyzing the demand for calories (see Bouis, Haddad, and Kennedy 1992 for a review). Nutritionists, in contrast, have long noted the importance of a wide range of macro- and micronutrients. A healthy human diet requires at least 51 known nutrients in consistently adequate amounts (Graham and Tetroe 2007); moreover, it is likely that there exist many synergies between nutrients, making dietary diversity an important concept in its own right. Nutritionists have therefore developed a wide range of dietary diversity indicators—ranging from detailed weighing of individual food intake to very simple recalls of broadly defined food groups—that have been shown to be strong predictors of adequate nutrient intake (Hatloy, Torheim, and Oshaug 1998; Shimbo et al. 1994; Foote et al. 2004; Steyn et al. 2006; Moursi et al. 2008) and health/nutrition outcomes (Arimond and Ruel 2004; Kant et al. 1993; Slattery et al. 1997; Levi et al. 1999). Economists, too, are increasingly exploring the merits of such indicators (Headey and Ecker 2013; Tiwari, Skoufias, and Sherpa 2013) and going beyond calories to examine the determinants of household demand for micronutrients (Ecker and Qaim 2011).

Yet despite growing interest in dietary diversity at the individual or household level, there is very little research on diversification of food supplies (hereafter DFS). After many years of focusing solely on calorie supply, the Food and Agriculture Organization of the United Nations (FAO) recently added a simple DFS measure—the share of calories supplied by nonstaple foods—to its expanded suite of food security indicators (FAO 2016). Headey (2013) shows that this indicator has stronger correlations with maternal and child undernutrition outcomes than the FAO estimates of total calories per capita, despite both indicators being derived from the same set of food balance sheets. Remans et al. (2014) likewise find that this indicator—along with other DFS indicators—is negatively correlated with national estimates of stunting, wasting, and underweight prevalence (but not overweight prevalence). Thus, as with individual and household measures of the diversity of diets, DFS is negatively associated with indicators of the prevalence of undernutrition and may therefore be a useful metric for monitoring how well a food system supplies a diverse range of nutrients at an aggregate level, which is a necessary but not sufficient condition for diverse diets among the population as a whole.

Yet despite these important rationales for measuring DFS, scarcely any research systematically studies the distribution of DFS across countries and the evolution of DFS over the course of economic development and structural transformation. In this study we first review various theories of the diversification of food demand and food supply, ranging from Bennett’s (1941) classic study of income growth as a driver of diversification out of staples, to microeconomic analyses of food demand, and micro- and macro-level studies of structural transformation and food system diversification in emerging economies. Based on this evidence we hypothesize that various processes of structural transformation (economic growth, urbanization, agricultural transformation, demographic transitions from older to younger populations, and rapid changes in education levels) are likely to be strong predictors of DFS. However, the limited tradability of many highly perishable foods also means that deeper structural factors in the agricultural sector may also explain long-run differences in DFS, even between countries at similar income levels. Some countries, for example, may have agroecological characteristics that leave them poorly suited to the production of animal-sourced foods or fruits and vegetables, neither of which are highly tradable across long distances.

We then describe the construction of a rich cross-country dataset (Section 3), which we then use to document some basic stylized facts regarding the distribution of DFS across countries, and the evolution of DFS over time and over the course of economic growth (Section 4). Consistent with expectations, DFS is strongly associated with economic growth and other structural transformation indicators, although some countries have unusually high or unusually low levels of DFS even after controlling for levels of economic development. For example, several countries with high levels of...
irrigation and rice production are characterized by unusually low DFS. In Section 5 we conduct more rigorous tests of these hypotheses using fixed-effects models (which only test the effect of time-varying structural transformation factors) and correlated-random-effects models (which also permit the inclusion of time-invariant structural factors, such as agroecological characteristics). We find that economic growth, urbanization, and demographic change explain DFS changes over time, but also that time-invariant structural factors (for example, land constraints and excess water constraints) substantially explain the persistence of DFS differences over time. Moreover, these results are robust to an alternative indicator of DFS—the share of calories sourced from animal foods—and to the inclusion of alternative explanatory variables (Section 6).

Section 7 concludes the paper with a discussion of the implications of this research. Our principal conclusion is that while structural transformation can indeed be expected to bring about DFS, some countries face greater structural barriers to this diversification process because of the particular characteristics of their agricultural production systems and the limited tradability of nutrient-rich nonstaple foods. This suggests a stronger rationale for food policies in such countries to focus more intensively on diversifying food supplies to increase the affordability of nutrient-rich foods, although behavioral change communications policies will also be needed to raise demand for such foods. How best to do so should be the subject of future research.
2. BACKGROUND

This section outlines some key literature with respect to the drivers of dietary diversification. First, we review some of the theory and evidence on the economic analysis of food demand systems. Second, we review additional non-income drivers of food demand, namely several processes of structural transformation: urbanization, demographic transitions, expansions in education, and agricultural transformation. Lastly, we explore the potential for agricultural policies to influence dietary diversification.

Income Growth and the Diversification of Diets (Bennett’s Law)

Although a sizable economic literature has estimated the relationship between availability or consumption of calories and household incomes (that is, estimating Engel’s law), the first known study to specifically look at diversification into less calorie-dense foods was Bennett’s (1941) analysis of the declining demand for wheat and other cereals. Bennett documented secular reductions in the demand for cereals, and showed that the share of staples in total food supply tended to decline as incomes rose. The underlying microeconomic explanation of this relationship is that poor households have incentives to buy cheap sources of calories to free up expenditures for nonfood goods and services; but as incomes increase consumers start to purchase more expensive calories that are generally tastier and often healthier (Subramanian and Deaton 1996; Skoufias 2003; Yu and Abler 2009; Jensen and Miller 2010; Logan 2006; Yu, Gao, and Zeng 2014; Timmer, Falcon, and Pearson 1983).

A few studies have identified the role of income in influencing dietary diversification. Theil and Finke (1983), using cross-sectional data for 30 countries, document that the diversity of food supplies increases as income per capita rises. Another cross-country study found that the number of foods consumed increases with rising income per capita (Falkinger and Zweimüller 1996). Similarly, Regmi (2001) finds that consumption of fruits and vegetables increases with income. The demand for more diverse diets is also indirectly informed by patterns of income elasticities for different food groups. Using cross-country data from the International Comparison Program, Seale, Regmi, and Bernstein (2003) and Muhammad et al. (2011) confirm that staple foods indeed have smaller income elasticities compared to nonstaple foods such as meat and dairy, and that those differences tend to rise with income. For instance, Seale, Regmi, and Bernstein (2003) estimate that the income elasticity for staples varies from 0.62 in Tanzania to just 0.05 in the United States.

Country-level studies also reveal diverse results, though there are consistent patterns of high income elasticities for animal-sourced foods, moderate elasticities for fruits, vegetables, pulses, legumes, and nuts, and low income elasticities for cereals. Using household-level data for India, Kumar et al. (2011) find income elasticities are highest for milk (1.64), followed by vegetables and fruits (0.82) and pulses (0.72), with a much lower income elasticity for rice (0.19). Average income elasticities derived from of a meta-analysis of studies from Africa south of the Sahara by Melo et al. (2015) are reported in Table 2.1. Cereal, legumes and nuts, and roots and tubers have low income elasticities, generally below 0.5. Interestingly, elasticities for fruits and vegetables are also relatively low (0.56 on average), but elasticities for animal products are much higher (0.90 on average). These results suggest that, at low income levels at least, income gains will translate into more diversified diets, although diversification into fruit and vegetable consumption may be relatively slow.¹

¹ This broad conclusion comes with two caveats, however. First, there is appreciable variation in elasticities across countries. Second, Melo et al. (2015) and other similar meta-analyses uncover substantial sensitivity to estimation methods. Cross-sectional data yield higher elasticities relative to panel data, expenditure data yield lower elasticities than income data, and demand system estimation provides results in larger estimates than single-equation approaches. But those caveats aside, there is clearly strong empirical support for an important role of income in driving dietary diversification.
Table 2.1 Results of a meta-analysis of income elasticities in Africa south of the Sahara by Melo et al. (2015)

| Food type              | Number of estimates | Weighted average* | Food type              | Number of estimates | Weighted average* |
|------------------------|---------------------|-------------------|------------------------|---------------------|-------------------|
| Cereals                | 762                 | 0.36              | Fruits and vegetables  | 218                 | 0.56              |
| Cereals                | 153                 | 0.59              | Bananas                | 6                   | 0.42              |
| Maize                  | 105                 | 0.15              | Fruits                 | 10                  | 0.51              |
| Rice                   | 58                  | 0.36              | Green and leafy veg    | 6                   | 0.49              |
| Millet                 | 37                  | 0.22              | Other vegetables       | 11                  | 0.46              |
|                        |                     |                   | Pumpkin                | 6                   | 0.73              |
|                        |                     |                   | Tomato                 | 6                   | 0.83              |
| Legumes and Nuts       | 124                 | 0.39              | Vegetables and fruit   | 165                 | 0.59              |
| Groundnuts             | 6                   | 0.54              |                        |                     |                   |
| Legumes and nuts       | 41                  | 0.54              |                        |                     |                   |
| Peas and beans         | 57                  | 0.21              |                        |                     |                   |
| Peas and soybeans      | 6                   | 0.43              | Dairy                  | 114                 | 0.83              |
| Pulses                 | 8                   | 0.50              | Miscellaneous          | 16                  | 1.03              |
| Regular beans          | 6                   | 0.75              | Eggs                   | 22                  | 0.75              |
|                        |                     |                   | Fish                   | 106                 | 0.78              |
| Roots and tubers       | 132                 | 0.34              | Meat                   | 152                 | 0.96              |
| Cassava                | 43                  | 0.32              | Meat and fish          | 25                  | 1.15              |
| Potatoes               | 7                   | 0.90              | Red meat               | 6                   | 1.10              |
| Sweet potatoes         | 1                   | 0.08              | White meat             | 6                   | 1.14              |
| Tubers                 | 55                  | 0.46              |                        |                     |                   |
|                        |                     |                   | Fat and oil            | 113                 | 0.60              |
|                        |                     |                   | Sugar and sweets       | 49                  | 0.63              |
|                        |                     |                   | Proc. beverages        | 96                  | 1.38              |

Source: Melo et al. (2015).
Notes: * Here we reported weighted averages for the aggregated food groups (bold) rather than raw averages, because the latter (as reported by Melo et al. [2016]) includes outliers. The weights we use are the number of studies per food group.

The Role of Broader Structural Transformation Processes

While economic studies of the demand for different foods chiefly focus on income, a much broader literature emphasizes that income growth is only one component of a multifaceted process of structural transformation that involves urbanization, agricultural transformation, demographic transitions, and increases in education (Timmer 2009a).

The earliest stage of development is characterized by predominantly rural agrarian populations operating small farms within autarkic economic systems, meaning that what people consume chiefly consists of whatever is or whatever can be grown locally. The underdevelopment of spatially integrated food markets exists because of both demand and supply constraints. Low income levels and population dispersion correspond to very limited demand for more nutrient-rich foods. On the supply side, agricultural markets in poor countries face very high transaction costs (de Janvry, Fafchamps, and Sadoulet 1991; Singh, Squire, and Strauss 1986). While these transaction costs might also hinder cereal markets (Minten, Stifel, and Tamru 2014), cereals are much less perishable than most fruits, vegetables, and animal-sourced foods (for example, dairy, eggs). This allows some trade in cereals but also permits poor farmers to store cereals during lean seasons, making them attractive as a means of ensuring basic food security. In contrast, many nutrient-rich foods are consumed only if they can be locally produced, which means that agroecological conditions can substantially determine consumption patterns in poor areas.

Agroecological conditions can affect both livestock and cropping decisions. Some agroecologies are very suitable for livestock ownership because of ample availability of feed, suitability of crops and soils to animal traction, and low prevalence of animal diseases such as tsetse fly (Pingali, Bigot, and Binswanger 1987), but regions without those properties may have low levels of livestock ownership. Africa, for example, has tremendous variation in cattle ownership based on those types of factors (Pingali,
Bigot, and Binswanger 1987). Likewise, agroecological conditions shape crop decisions. For example, in large parts of Bangladesh annual monsoonal flooding creates waterlogged conditions that are essentially favorable only for rice production, making diversification out of rice agronomically difficult in the monsoon season (Pingali 2007). In contrast, somewhat drier conditions, or sloping areas, may be better suited to vegetable and fruit production because of better drainage. In general one would expect the importance of such agroecological factors for food supplies to decline in influence as economies develop and become more intensive in both domestic and international trade in foods. Remans et al. (2014) present evidence consistent with that prediction using FAO food balance sheet data, while a large number of household-based studies find strong associations between on-farm production and consumption patterns (see Carletto et al. 2015 for a review).

Beyond income constraints, some countries may also impose additional policy constraints to agricultural diversification. Over the past 50 years, agricultural development strategies in poor countries have been heavily biased toward the production of staple foods, such as rice, wheat, and maize, with relatively few large-scale success stories in nutrient-rich nonstaple foods. Although investment in staples is often estimated to be essential for poverty reduction, the effects of such investment on dietary diversification is uncertain. Masters et al. (forthcoming) find that many countries subsidize staples over nonstaples, though these estimates apply only to tradable foods, and many nonstaples are largely nontradable. Headey and Hoddinott (2016) more directly test whether growth in yields of Bangladesh’s main staple, rice, explains subnational trends in dietary diversification and nutrition outcomes for young children. They find that changes in rice yields explain reductions in wasting, but that yield growth had no discernible effect on dietary diversity of children, or stunting rates. They argue that pro-poor value chains for nutrient-rich foods such as dairy, poultry, and fruits and vegetables may emerge only slowly without public support, such as the Indian government’s important role in expanding India’s dairy production (Cunningham 2009). In addition to policy biases toward staples, poor infrastructure is likely to be an important constraint to agricultural diversification, since staple foods tend to be much less perishable than nonstaple foods. To our knowledge, however, no previous research has explicitly tested this hypothesis.

Agricultural transformation also emerges as countries start to urbanize. The development of larger urban markets with high concentrations of wealthier consumers fosters more sophisticated value chains for nutrient-rich foods. Such value chains will often entail improved logistics and transport, more attention to access to finance and other essential services, and the transition from small-scale informal food retail markets to supermarkets (Pingali 2007; Reardon and Timmer 2012). The emergence of these value chains can have transformative feedback effects on the agricultural sector, especially those with good access to urban centers, which allows them to concentrate production into higher-value products. Some value chains can also develop for imported food products, which offers scope for the agricultural sector to concentrate production on products for which it has a comparative advantage.2

Two other transformations of potential relevance are the demographic transition (declining fertility rates and age dependency ratios) and increased educational attainment (particularly women). As the proportion of children in a given population declines, disposable incomes tend to increase (Bloom and Williamson 1998). But a potential secondary effect of reduced age dependency ratios may operate through parents being able to devote more resources to a child when there are fewer children in aggregate to take care of (Becker and Lewis 1973). It is plausible that having few children leads parents to demand higher-quality nutrient-rich foods. And independent of any effects on fertility rates, education may increase the demand for nutrient-rich foods because of improved nutritional knowledge (Alderman and Headey 2014; Block 2004; Webb and Block 2004).3

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2 Remans et al. (2014), for example, cite the case of Malaysia, whose agricultural sector has been allowed to increasingly specialize in palm oil production as its food system increasingly relies on imports.

3 However, the education of girls could ultimately stimulate greater female labor force participation, which may increase the demand for less-time-consuming processed foods (Reardon and Timmer 2012).
3. DATA AND METHODS

Data

In this paper we use a cross-country panel dataset that merges data from a variety of sources. Food balance sheets from the FAO containing data on the supply of calories, proteins, and fats from different food groups (for example, cereals, vegetables) have been used to create a very simple measure of diversity of food supply, which is our outcome variable: calories supplied from nonstaple foods, where staple foods include cereals and root crops. These data have well-known weaknesses. Conceptually, they do not measure the composition of diets per se but only food supply, and much food may be wasted. Empirically, the underlying quality of national data sources that go into FAOSTAT is often poor in low-income countries. Nevertheless these data remain the only comprehensive means of comparing the calorie content and diversity of food supplies across countries and over time, and as we show below, they do yield indicators that predict nutrition outcomes such as child stunting and anaemia rates. Moreover, while they may be measured with error (Del Gobbo et al. 2015), we show below that the cross-country pattern for these indicators is indeed consistent with economic theory.

We use private consumption expenditure per capita (measured in international purchasing power parity [PPP] dollars from the World Bank [2016]) as the most suitable indicator of household purchasing power (since gross domestic product per capita includes government expenditures that may be less relevant for influencing food demand). We use average years of schooling attained, measured at five-year intervals, as our indicator for education (Barro and Lee 2010). We use share of urban population and the share of children in the population aged 0–14 years as indicators of urbanization and the demographic transition (World Bank 2016). The World Bank (2009) also reports data on measures of topography (hills and mountains, lowland areas) that might influence production diversity. For example, hill areas are suitable for orchards, whilst wet lowland areas tend to be less suitable for vegetable production. Likewise rural population density can be considered a proxy for land constraints. Smaller farms may encourage diversification into higher-value crops (Boserup 1965) or small farms may proxy for rural poverty and various market failures (for example, in rural land markets), which may constrain demand for more nutrient-rich foods. Likewise, land constraints typically result in feed constraints, which limits the scope for livestock production. For infrastructure indicators, we include road density, international shipping costs, and electric power consumption in this sample. Though time-varying in principle, these indicators are only available for fixed points in time. Another set of time-invariant geographical characteristics (from WorldClim 2016—a global climate database) contains data on average monthly rainfall and standard deviation. Cross-country average groundwater values have also been derived from a global groundwater database (Fan et al. 2013). Water availability could have complex relationships with production diversity. More rainfall, and more stability in rainfall, might reduce risk and encourage poor farmers to diversify production. On the other hand, too much water—especially groundwater—can lead to waterlogged soils that are poorly suited for vegetable production, leaving rice, in particular, as the only option for water-abundant lowland systems.

After integrating the datasets, we have a five-year unbalanced panel dataset of 51 countries (low-to high-income countries) for the period 1965–2010, with a sample of 557 observations, although the actual sample size used varies according to the model specification (Table A.1 in the appendix lists the countries). Table 3.1 reports definitions of our dependent and independent variables, and Table 3.2 reports descriptive statistics. The sample covers ample variation in DFS, and in the main indicators of structural transformation, although we also test robustness to sample restrictions.
| Variable                                      | Definition                                                                                                                                                                                                 |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Diversity of food supply                      | The share of calories not derived from starchy staples: cereals, roots, tubers, and plantains                                                                                                               |
| Calories supplied from nonstaples             | The share of calories not derived from starchy staples: cereals, roots, tubers, and plantains                                                                                                               |
| Proteins from animal-sourced foods            | Share of proteins supplied by any food of animal origin                                                                                                                                                   |
| Consumption per capita                        | Household final consumption expenditure per capita is the market value of all goods and services, purchased by households                                                                                     |
| Education (years)                             | Average years of schooling attained in five-year intervals                                                                                                                                                 |
| Urban population (% of total population)       | Share of people living in urban areas                                                                                                                                                                     |
| Population ages 0–14 (% of total)             | Share of children in the population aged 0–14 years                                                                                                                                                       |
| Time-invariant geographical and infrastructural characteristics |
| Rural population density                      | The population estimated to be rural divided by agricultural land                                                                                                                                         |
| Electricity consumption (kWh per capita)      | The production of power plants less power plant use, transmission, distribution, and transformation losses, divided by midyear population                                                                      |
| Road density (%)                              | Total length of the road network—includes the length of the paved and unpaved portions divided by country land area                                                                                         |
| Shipping costs                                | Country ranking of international shipping costs                                                                                                                                                            |
| Groundwater depth (meters)                    | Average groundwater values in total land area                                                                                                                                                              |
| Hills and mountains (% of total land area)     | The share of hill and mountain areas                                                                                                                                                                      |
| Lowlands (% of total land area)               | The share of lowland areas in total land area                                                                                                                                                              |
| Suitable land (%)                             | The share of land suitable in total land area                                                                                                                                                               |
| Rainfall (mm)                                 | Average monthly rainfall, 1980–2000                                                                                                                                                                         |
| Rainfall_std (mm)                             | Standard deviation of monthly rainfall over 1980–2000                                                                                                                                                    |

Source: FAO (2016); World Bank (2009, 2016); Barro and Lee (2010); WorldClim (2016).
Notes: kWh = kilowatt-hours.

Table 3.2 Descriptive statistics for key variables

| Variable                                      | Observations | Mean   | Standard deviation | Min  | Max  |
|-----------------------------------------------|--------------|--------|--------------------|------|------|
| Share of calories supplied from nonstaples    | 557          | 0.49   | 0.16               | 0.14 | 0.78 |
| Share of proteins from animal-sourced foods   | 557          | 0.40   | 0.17               | 0.09 | 0.70 |
| Consumption expenditure (constant PPP $)      | 557          | 5753.96| 5906.03            | 144.33| 27044.62|
| Education (years)                             | 557          | 5.92   | 2.83               | 0.13 | 12.03|
| Urban population (% of total population)       | 557          | 51.59  | 20.96              | 3.58 | 92.49|
| Population ages 0–14 (% of total population)  | 557          | 34.11  | 10.32              | 13.29| 49.97|
| Electric power consumption (kWh per capita)   | 557          | 27.20  | 25.40              | 0.03 | 99.32|
| Road density (roads per 1,000 sq. km)         | 557          | 74.59  | 90.72              | 3.60 | 372.20|
| Shipping costs (global rank)                  | 557          | 70.31  | 46.68              | 2.00 | 169.00|
| Suitable land (%)                             | 557          | 61.92  | 21.82              | 20.64| 97.63|
| Population density (per 1,000 m²)             | 557          | 111.82 | 164.52             | 0.39 | 1164.14|
| Hills and mountains (% of total land area)    | 557          | 0.52   | 0.30               | 0.00 | 1.00 |
| Lowlands (% of total land area)               | 557          | 0.25   | 0.23               | 0.00 | 1.00 |
| Groundwater (meters)                          | 557          | 1.91   | 1.19               | 0.07 | 4.82 |
| Average rainfall (mm)                         | 557          | 90.85  | 49.53              | 27.60| 227.00|
| Rainfall variation (mm)                       | 557          | 51.39  | 39.95              | 6.40 | 169.50|

Source: FAOSTAT (2016); World Bank (2013); Barro and Lee (2010); WorldClim (2016).
Notes: PPP = international purchasing power parity; kWh = kilowatt-hour.
Methods

In terms of methods, we implement a variety of statistical techniques via Stata version 14.0. Graphically, we apply nonparametric techniques, specifically the local polynomial smoother with 95 percent confidence intervals (the `lpolyci` command) to assess nonlinear relationships in key parameters of interest. To explore factors that might influence DFS, we first estimate fixed-effects (FE) models to assess the associations between diversity of food supply (DFS) for a country \(i\) and time \(t\) and a vector of time-varying intermediate determinants (\(X\): consumption, education, urbanization, and population 0–14 years), country fixed effects (\(\mu_i\)), and trend effects represented by a vector of year dummy variables (\(T\)). The vector of coefficients (\(B\)) constitutes the set of parameters of principal interest. With the addition of an error term (\(\varepsilon_{it}\)), we represent the relationship by equation 1:

\[
DFS_{it} = \alpha + \beta \log X_{it} + T_t + \mu_i + \varepsilon_{it}. \tag{1}
\]

But while FE models are useful for controlling for a range of time-invariant effects that might be correlated with time-varying factors like mean consumption levels or education, a disadvantage of such models is that researchers are sometimes directly interested in the impacts of time-invariant factors such as agroecological constraints and transport costs (for reasons described in Section 2). We therefore utilize the correlated-random-effects (CRE) model, also called the Chamberlain–Mundlak model following Mundlak (1978) and Chamberlain (1984), to account for the panel structure in the data whilst still allowing coefficients of time-invariant independent variables to be identified. In this model, fixed effects are effectively replaced with country averages of time-varying indicators as well as a vector of time-invariant indicators of interest (for example, agroecological indicators). This model still therefore specifies within-country effects of time-varying indicators (such as growth in consumption per capita) but allows us to test associations between time-invariant factors and DFS. The key assumption is that the remaining unobserved heterogeneity is uncorrelated with the independent variables.

The CRE model therefore takes the form

\[
DFS_{it} = \alpha + \beta \log X_{it} + \theta \log \bar{X}_i + \gamma z_i + T_t + \varepsilon_{it}, \tag{2}
\]

where DFS refers to share of calories from nonstaples for country \(i\) and time \(t\); \(\beta\) refers to the impact of log of consumption per capita on calories supplied from nonstaples; \(X\) refers to various time-varying determinants of diversity of food supply such as education, urban population, and population ages 0–14 years; \(T\) refers to time dummies; \(\bar{X}_i\) includes time averages of all covariates; \(z_i\) is a vector of time-invariant variables related to geographical characteristics; and \(\varepsilon\) is an error term. \(\beta\) can be interpreted as the fixed-effects “within-country” estimate of the predicted impact of changes over time in \(X\) on changes in DFS.
4. DESCRIPTIVE RESULTS

How does DFS vary across regions and income levels? In this section we assess patterns and trends in DFS to understand some basic stylized facts. Figure 4.1 presents a map of the DFS across countries for 2010, with darker shades of blue representing greater DFS. Unsurprisingly, the map indicates that North America, Western Europe, Australia, New Zealand, and several Latin American countries show the highest levels of diversity of food supply, followed by Eastern Europe, Japan, several Latin American countries (for example, Mexico, Chile), and Japan. In contrast, South Asian countries have low DFS, particularly Bangladesh and Nepal. In Africa there is some heterogeneity, but DFS is very low in West Africa, Ethiopia, and much of southern Africa.

**Figure 4.1 Calories supplied from nonstaples across countries, 2010**

![Map of DFS across countries](image)

Source: Authors’ estimates from FAO (2016) data.
Notes: Each country is colored according to value of corresponding diversity of food supply.

Our primary interest in analyzing DFS is how well it predicts undernutrition. Previous research has shown the share of calories sourced from non-staple foods is actually quite a strong predictor of child stunting and wasting rates in developing countries (Headey and Ecker 2013; Remans et al. 2014), but Del Gobbo et al. (2015) find that FAO per capita food supply estimates are poor predictors of individual consumption measures from household surveys. In Figure 4.2 we look at how closely this simple DFS measure associates with a child-level dietary diversity indicator (for children aged 6–24 months) from the Demographic and Health Surveys (DHS 2016): the minimum diet diversity (MDD) indicator. That indicator measures the percentage of children receiving four or more of seven food groups. Although these two indicators are conceptually very different, the MDD and DFS indicators are significantly and positive correlated (0.39, significant at 1 percent level), though there is certainly variation around the predicted relationship (Figure 4.2). For example, Uganda (UGA) has low MDD relative to DFS, but Indonesia (IDN) has high MDD relative to its DFS. Overall, however, Figure 4.2 suggests that DFS is indeed a significant predictor of child-level dietary diversity.4

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4 It would also be useful to know how well DFS predicted maternal dietary diversity, but the Demographic and Health Surveys no longer measure this.
Figure 4.2 LOWESS and scatter plots of the association between the percentage of 6-to-24-month-old children having a minimal acceptable diet and the diversity of food supply (share of calories from nonstaples)

Source: Authors’ estimates from FAO (2016) and DHS (2016) data.
Notes: The solid line is an lpoly plot estimated in Stata 14. LOWESS = locally weighted scatterplot smoothing. Three-letter World Bank country codes denote specific observations. The full list of corresponding country codes can be found at: http://wits.worldbank.org/WITS/wits/WITSHELP/Content/Codes/Country_Codes.htm.

In Figure 4.3 we look at the relationship between DFS and household consumption per capita in 2010 for countries with consumption levels of below $4,000 per capita (essentially low- and lower-middle-income countries). The red line is a LOWESS plot showing the predicted relationship between consumption per capita and DFS, which is somewhat concave, suggesting that the association between consumption and DFS gradually weakens with rising consumption levels. However, the scatter plot—which reports three-letter World Bank country codes—also shows substantial variation around this mean relationship. Some of that variation may be because per capita consumption does not take into account inequality in consumption, but some of the variation is plausible related to agroecological factors. For example, although very poor, Somalia (SOM) is estimated to have unusually high DFS because of the exceptionally important role of animal-sourced foods in a predominantly pastoral or agropastoral economy (Mongolia is similar in this regard).\textsuperscript{5} At the other extreme are several countries that are notable negative outliers, with DFS levels that are much lower than one would expect from their consumption levels. Notable in this regard are several countries heavily reliant on irrigation or rice production, or both, such as Madagascar (MDG), Bangladesh (BDG), Laos (LAO), Cambodia (KHM), Indonesia (IDN), and Egypt (EGY). This observation is consistent with agroecological constraints to diversification that are associated with these types of farming systems, including high population density (lack of animal feed), high water tables that might inhibit fruit and vegetable production, and perhaps also rice-based consumption cultures.

\textsuperscript{5} Clearly, however, food balance sheet data for Somalia should be treated with great caution.
Figure 4.3 LOWESS and scatter plots of diversity of food supply (percentage of calories from nonstaples) against household consumption per capita for low- and lower-middle-income countries, 2010

![Graph showing LOWESS and scatter plots of diversity of food supply against consumption per capita.](image)

Source: Diversity of food supply is sourced from FAO (2016), and consumption per capita is sourced from the World Bank (2016).

Notes: The solid line is an lpoly plot estimated in Stata 14. LOWESS = locally weighted scatterplot smoothing; PPP = purchasing power parity. Three-letter World Bank country codes denote specific observations. The full list of corresponding country codes can be found at: http://wits.worldbank.org/WITS/wits/WITSHELP/Content/Codes/Country_Codes.htm.

Table 4.1 and Figure 4.4 offer a more dynamic picture of the evolution of DFS over time and over the course of economic development. Table 4.1 reports trends in DFS for income groups, major regions, and countries over the 1961–2010 period. For income groups (as defined by 2010 data), the major result is that dietary diversification was slow in the poorest income groups, with just a 5 percentage point increase over the time period for both the low-income and lower-middle-income groups. In contrast, upper-middle-income and high-income Organization for Economic Cooperation and Development groups saw 11-point and 9-point changes over this period. Regionally, Latin America and the Caribbean saw moderate changes on average, though changes in countries like Mexico and Brazil were rapid (14-point changes in both countries). Africa south of the Sahara has seen very little diversification in food supplies, just 5 points on average, and there is relatively little variation in DFS changes (or, at least, no country experiencing rapid improvements). In South Asia, Pakistan saw a sizable improvement in DFS (11 points), but changes in India and Bangladesh were very modest (3 and 4 points). In East Asia and the Pacific there was similar variation: China and Vietnam experienced dramatic increases in DFS (25 and 23 points, respectively), but Indonesia saw only a modest 6-point increase.
Table 4.1 Trends in calories supplied from nonstaples for income groups, major regions, and countries, 1961–2010

| Variable                        | Sample median: 1961 | Sample median: 2010 | Change in median |
|---------------------------------|---------------------|---------------------|------------------|
| High-income OECD                | 61%                 | 70%                 | 9%               |
| Japan                           | 34%                 | 58%                 | 24%              |
| Upper-middle-income             | 44%                 | 55%                 | 11%              |
| Lower-middle-income             | 35%                 | 40%                 | 5%               |
| Lower-income                    | 25%                 | 30%                 | 5%               |
| Latin America and Caribbean     | 48%                 | 55%                 | 7%               |
| Mexico                          | 41%                 | 55%                 | 14%              |
| Brazil                          | 50%                 | 65%                 | 14%              |
| SSA                             | 32%                 | 36%                 | 5%               |
| Nigeria                         | 34%                 | 34%                 | 0%               |
| Kenya                           | 34%                 | 41%                 | 7%               |
| South Asia                      | 30%                 | 37%                 | 7%               |
| India                           | 36%                 | 39%                 | 3%               |
| Pakistan                        | 40%                 | 51%                 | 11%              |
| Bangladesh                      | 15%                 | 19%                 | 4%               |
| East Asia and Pacific           | 33%                 | 43%                 | 10%              |
| Vietnam                         | 16%                 | 39%                 | 23%              |
| China                           | 23%                 | 48%                 | 25%              |
| Indonesia                       | 23%                 | 29%                 | 6%               |

Source: FAO (2016).
Note: OECD = Organization for Economic Cooperation and Development; SSA = Africa south of the Sahara.

Clearly one explanation of the patterns in Table 4.1 is the variation in income growth across counties. Figure 4.4 therefore plots DFS trajectories against changes in consumption per capita. Panel A focuses on Asian countries and Panel B on African countries. In Panel A, China offers a remarkable example of extremely rapid diversification of food supplies. In the 1970s nonstaple foods accounted for just 20 percent of China’s calorie supply, but as economic growth accelerated from 1978 onward that ratio rose to almost 50 percent. Thailand has followed a somewhat similar trajectory, as has Vietnam (not shown). But other Asian countries have seen relatively slow diversification of food supplies. Like China and Thailand, Indonesia had similar dependence on rice and other staples in the 1960s and 1970s, but Indonesia’s food basket appears to have diversified slowly, with nonstaples accounting for just 30 percent of the total supply of calories by 2010. Moreover, this slower diversification is only partly explained by lower rates of economic growth: Indonesia’s food supply in 2010 was much less diversified than Thailand’s was in 1990, when their income levels were comparable. India appears to follow a more intermediate trajectory. Diversification during the 1970s and 1980s (the heyday of India’s Green Revolution in wheat and rice) was very modest, but it picked up during the 1990s and 2000s during a period of more rapid economic growth. Bangladesh has experienced more modest but solid growth in consumption since the mid 1990s, and its food supply has begun to diversify from its extremely low base. However, its food supply in 2010—when annual consumption averaged about $1,000 per capita—is about half as diversified as China’s food supply at a comparable level of consumption (19 percent versus 37 percent).
In Panel B we look at African countries. Egypt has followed a flat DFS trajectory, with scarcely any diversification of the diet over the course of reasonably rapid and prolonged growth in average consumption. Ethiopia has even lower levels of consumption, but recent economic growth also appears to be translating into a more diverse food supply. Ghana follows a similar pattern, albeit from a more diversified starting point. Finally, Madagascar is a contrary example of a country where per capita consumption has actually fallen over time, from around $1,300 per capita in 1970 to just $700 per capita in 2010. As expected, diets have become substantially less diverse.
Overall, DFS appears to be very strongly associated with levels of development in general, and per capita consumption levels and growth rates. That said, there are striking deviations from this expected relationship that are likely related to factors not captured by average income. Most notably, DFS is exceptionally low in several countries characterized by high rates of rice production and irrigation. In such countries growth in per capita consumption still seems to be driving diversification of food supplies, but from a much less diversified base (for example, Bangladesh) and in some cases at a much slower rate (for example, Indonesia, Egypt).
5. REGRESSION RESULTS

Table 5.1 reports FE and CRE regressions of diversity of food supply against time-varying indicators of structural transformation, as well as a series of time-invariant indicators of infrastructure and agroecological characteristics. The regressions are semi-log, meaning that all coefficients reflect the change in the share of calories supplied from nonstaples resulting from a 100 percent increase in the explanatory variable. Hence the coefficients of the different indicators are highly comparable. We also note that both the FE and CRE models produce high coefficients of determination, suggesting that these specifications do a good job in predicting spatial and temporal variation in DFS.

Table 5.1 Correlated-random-effects and fixed-effects regressions of the semi-log DFS model

| Estimator | FE          | CRE          |
|-----------|-------------|--------------|
| Time-varying indicators                      |             |              |
| Consumption per capita                       | 0.055***    | 0.059***     |
|                                                  (0.006) | (0.012)     |
| Education (years)                             | 0.006       | 0.014        |
|                                                  (0.012) | (0.024)     |
| Urban population                              | 0.066***    | 0.067***     |
|                                                  (0.011) | (0.023)     |
| Population ages 0–14 years                    | -0.095***   | -0.088**     |
|                                                  (0.018) | (0.036)     |
| Time-invariant indicators                      |             |              |
| Electricity consumption                        | -0.003      |              |
|                                                  (0.012) |             |
| Road density                                   | 0.039***    |              |
|                                                  (0.004) |             |
| Shipping costs                                 | -0.002      |              |
|                                                  (0.004) |             |
| Suitable land                                  | 0.024***    |              |
|                                                  (0.007) |             |
| Population density                             | -0.114***   |              |
|                                                  (0.012) |             |
| Hills and mountains                            | 0.006**     |              |
|                                                  (0.003) |             |
| Lowland areas                                  | 0.002       |              |
|                                                  (0.003) |             |
| Groundwater depth                              | -0.014***   |              |
|                                                  (0.005) |             |
| Average rainfall                               | -0.028***   |              |
|                                                  (0.010) |             |
| Rainfall variation                             | -0.011      |              |
|                                                  (0.007) |             |
| Time effects                                    | Yes         | Yes          |
| R-squared                                       | 0.870       |              |
| R-squared within                               | 0.624       |              |
| Number of observations                         | 557         | 557          |

Source: Authors’ estimates.
Notes: CRE = correlated-random-effects; FE = fixed-effects. * p < 0.10. ** p < 0.05. *** p < 0.01. Standard errors are in parentheses.
As the nonparametric results suggested, per capita consumption expenditure is a strong predictor of changes in diversity of food supply, even in terms of within-country effects. For every doubling of household consumption expenditure, calories supplied from nonstaples will go up by nearly 6 percentage points, an association that is strongly significant at the 1 percent level in both FE and CRE regressions. However, other indicators of structural transformation are also highly significant. Indeed, point estimates of the partial elasticity of DFS with respect to urbanization are somewhat larger than that of consumption per capita (though not significantly so). Even more strikingly, the population aged 0–14 years has a large, negative, and highly significant association with DFS in both the FE and CRE models. Moreover, these associations are significantly larger than the coefficients on consumption per capita. Perhaps surprisingly, however, we do not find any significant association between the years-of-education variable and DFS.

As noted in Section 3, the CRE model also allows us to test associations between DFS and time-invariant factors, such as infrastructure variables and agroecological indicators. In terms of transport infrastructure, the partial elasticity for road density is 0.04, while the elasticity associated with shipping costs is insignificant. This likely reflects the fact that many nutrient-rich foods are highly perishable and are not shipped large distances. For example, eggs are scarcely traded at all across international borders (FAO 2016).

Consistent with economic theories of highly imperfect markets in underdeveloped rural settings, we observe some significant associations between DFS and various agroecological characteristics. Land suitability for crop production is positively and significantly associated with DFS, though the estimated partial elasticity is modest in magnitude (0.02). More strikingly, rural population density has a relatively large and negative partial elasticity of -0.11. We interpret rural population density as a proxy for land constraints, which may operate through several channels, such as feed constraints that inhibit production of animal-sourced foods, and a greater prevalence of small farms that push farmers into intensive cereal cultivation. Lowland areas have an insignificant association, but hilly and mountainous countries appear to have somewhat higher DFS. Groundwater depth has a negative association with DFS, but rainfall is also negatively associated with DFS. These results suggest that the relationship between water supply and diversification may be quite complicated (Headey and Hoddinott 2016).

Finally, both models produce large coefficients of determination, suggesting that these specifications do a good job in predicting spatial and temporal variation in DFS. In the FE model the within R-squared is 0.62, suggesting that these four structural transformation indicators explain around two-thirds of the changes in DFS over time. The aggregate R-squared in the CRE model factors in the explanatory power of both time-varying and time-invariant factors, but it is worth noting that the time-invariant factors explain a high share of the total variation in DFS (56 percent). Overall, the results support Bennett’s (1941) prediction that economic growth leads to diversification of food supplies, but the models are also highly consistent with broader theories of structural transformation and microeconomic theories of market failures in agrarian settings (Section 2).

We now use these regression results to analyze the predicted sources of DFS change over time using a simple decomposition at means technique, the results of which we report in Table 5.2.6 These decompositions are based on the fixed-effects regressions reported above, since the time-invariant indicators in the CRE model obviously cannot explain changes over time. The first column reports the estimated coefficient from that regression. The next three columns respectively report the 1961 and 2010 sample means and the change in means across time. The last column reports the share of predicted change accounted for by each variable. To see how these figures are derived, consider the second row of column 5 of Table 5.2, which reports the predicted change in DFS, which is the mean change in consumption per capita from 1961 to 2010 multiplied by the coefficient of consumption per capita on DFS from regression 1 in Table 5.1. This calculation suggests that increases in consumption per capita from 1961 to 2010 resulted in a 0.06 percentage point increase in the share of calories supplied from nonstaples. In other

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6 A more flexible alternative to a simple decomposition at means is a Oaxaca–Blinder decomposition, which allows coefficients to vary over time. However, the relatively small size of our sample produces some instability in the size of the coefficients when we restrict regressions to a single cross-section.
words, among the sources of predicted change, consumption per capita stands out as the single largest factor, explaining 41 percent of the predicted change in diversity of food supply. In addition to the modest impact of consumption per capita, we observe sizable contributions from urbanization (0.04) and reductions in the share of the population aged 0–14 (0.04). In aggregate the model predicts an average change in DFS of 13 percentage points, which is slightly more than the actual change observed (11 points). Overall, though, it appears that these three structural transformation indicators do a good job of predicting changes in DFS over time.

Table 5.2 Decomposing sources of DFS change for the full sample, 1961–2010

| Variable                  | Estimated β | Sample mean: 1961 | Sample mean: 2010 | Change in mean | Predicted DFS change | Share of predicted DFS change |
|---------------------------|-------------|-------------------|-------------------|----------------|-----------------------|-------------------------------|
| Diversity of food supply  | 0.43        | 0.52              | 0.10              | 0.13           | 100%                  |                               |
| Consumption per capita    | 0.06        | 7.58              | 8.58              | 1.00           | 0.06                  | 41%                           |
| Urban population           | 0.07        | 3.47              | 4.09              | 0.62           | 0.04                  | 31%                           |
| Population ages 0–14      | -0.10       | 3.63              | 3.23              | -0.40          | 0.04                  | 28%                           |

Source: Authors’ estimates.

Notes: DFS = diversification of national food supplies.
6. ROBUSTNESS TESTS

In this section we engage in a series of robustness checks designed to establish the extent to which the results presented in the previous section stand up to alternative specifications and to a more confident causal interpretation.

Table 6.1 reports FE and CRE regression results using an alternative indicator of DFS: the share of proteins supplied by animal-sourced foods (ASF supply). While dietary diversity in general may be beneficial for nutrition, animal-sourced foods have been identified as particularly important for child growth outcomes and of course for reducing deficiencies in key micronutrients (Hoppe, Molgaard, and Michaelsen 2006; Ianotti, Muehlhoff, and McMahon 2013; Iannotti et al. 2014; Murphy and Allen 2003). Overall the pattern of coefficients in Table 6.1 is very similar to that of Table 5.1, though there are some differences as well. The coefficients on consumption are somewhat larger in the context of ASF supply, which is consistent with the pattern of income elasticities reported in Table 2.1, where those pertaining to animal-sourced foods were larger than nonprocessed non–animal-sourced foods. One difference in the animal-sourced food results is that the coefficient on urbanization is insignificant in all the regressions reported in Table 5.1, but the share of the population aged 0–14 years still yields a large and negative elasticity. The CRE results reveal positive but modest associations between ASF supply and electricity supply and road density, but there is again no association with shipping costs. As with the result in regression 4, land suitability is positively associated with ASF supply but population density is negatively associated, which may reflect lack of feed or other sources of comparative disadvantage in producing animal-sourced foods. Groundwater depth is again negatively associated with the dependent variable, but rainfall has a positive association with ASF supply, perhaps indicating the importance of rainfall for increasing feed availability.

Table 6.1 Correlated-random-effects and fixed-effects regressions of the semi-log DFS model using alternative indicator of diversity of food supply: Protein share of animal-sourced foods

| Estimator                                | FE         | CRE         |
|------------------------------------------|------------|-------------|
| **Time-varying indicators**              |            |             |
| Consumption per capita                   | 0.063***   | 0.059***    |
| (0.008)                                  | (0.012)    |             |
| Education (years)                        | 0.012      | 0.011       |
| (0.015)                                  | (0.024)    |             |
| Urban population share                   | 0.023      | 0.030       |
| (0.014)                                  | (0.023)    |             |
| Population aged 0–14 years               | -0.155***  | -0.017***   |
| (0.023)                                  | (0.037)    |             |
| **Time-invariant indicators**            |            |             |
| Electricity consumption                  | -0.004     |             |
| (0.012)                                  |             |             |
| Road density                             | 0.012**    |             |
| (0.004)                                  |             |             |
| Shipping costs                           | -0.001     |             |
| (0.004)                                  |             |             |
| Suitable land                            | 0.031***   |             |
| (0.007)                                  |             |             |
| Population density                       | -0.128***  |             |
| (0.011)                                  |             |             |
| Hills and mountains                      | -0.006*    |             |
| (0.003)                                  |             |             |
| Lowland areas                            | 0.006      |             |
| (0.003)                                  |             |             |
### Table 6.1 Continued

| Estimator               | FE       | CRE       |
|-------------------------|----------|-----------|
| Groundwater depth       | -0.034***| (0.005)   |
| Average rainfall        | 0.040*** | (0.010)   |
| Rainfall variation      | -0.010   | (0.007)   |
| Time effects            | Yes      | Yes       |
| R-squared               | 0.541    | 0.885     |
| R-squared within        | 0.541    | 0.885     |
| Number of observations  | 557      | 557       |

Source: Authors’ estimates.

Notes: CRE = correlated-random-effects; DFS = diversification of national food supplies; FE = fixed-effects. * \( p < 0.10 \)  ** \( p < 0.05 \)  *** \( p < 0.01 \). Standard errors are in parentheses.

Table 6.2 reports results from adding an alternative indicator of education. The education indicator used in the previous section was years of schooling from Barro and Lee (2010) but Cohen and Soto (2007) criticized the quality of that data and produced an alternative series measured every 10 years. The coefficient on years of education is still insignificant, however, and there is no evidence that education contributions to DFS above and beyond any impact it has on the other three structural transformation processes.

### Table 6.2 Fixed-effects regressions of the semi-log DFS model using an alternative indicator of education

| Dependent variable                          | Fixed effects Calories from nonstaples | Fixed effects Calories from nonstaples |
|---------------------------------------------|----------------------------------------|----------------------------------------|
| Education (years) (Barro and Lee)           | 0.006                                  | 0.028                                  |
|                                             | (0.012)                                | (0.018)                                |
| Education (years) (Cohen and Soto)          |                                        |                                        |
| Consumption per capita                      | 0.055***                               | 0.051***                               |
|                                             | (0.006)                                | (0.009)                                |
| Urban population                            | 0.066***                               | 0.061***                               |
|                                             | (0.011)                                | (0.014)                                |
| Population 0–14 years                       | -0.095***                              | -0.119***                              |
|                                             | (0.018)                                | (0.025)                                |
| Time effects                                | Yes                                    | Yes                                    |
| R-squared within                            | 0.624                                  | 0.662                                  |
| Number of observations                      | 557                                    | 304                                    |

Source: Authors’ estimates.

Notes: DFS = diversification of national food supplies. * \( p < 0.10 \)  ** \( p < 0.05 \)  *** \( p < 0.01 \). Standard errors are in parentheses.

Next, we consider a series of different indicators of agricultural and trade policies—tariff rate, agricultural tax and subsidy, price level of consumption, and public spending on agriculture. These indicators were not available for all countries and all years, and were therefore omitted from the results reported in the previous section. Table 6.3 reports FE results from including these indicators. In regression 1 we include indicators of real rates of assistance to agriculture (RRA) from the World Bank agricultural distortions database (Anderson 2008). We bifurcate the RRA indicators into subsidies and taxes to allow for asymmetric effects. Positive RRA values are agricultural subsidies and negative RRA
values are agricultural taxes. We find a positive and significant partial elasticity of DFS with respect to agricultural subsidies, though the association is small in magnitude (0.02). We find no effects of agricultural taxation. For a smaller subset of countries we also tested whether subsidization of staple foods had any association with DFS, but we found no evidence that it did (results available on request). However, the Anderson (2008) study found that in developing countries relatively few fruits, vegetables, and animal-sourced foods were internationally tradable, and hence RRA values for those food groups are missing for many developing countries.

Table 6.3 Fixed-effects regressions of the semi-log DFS model using alternative indicators of agricultural and trade policies

| Estimator                  | Fixed effects |
|----------------------------|---------------|
| Consumption per capita     | 0.053***      |
|                            | (0.010)       |
| Education (years)          | 0.002         |
|                            | (0.017)       |
| Urban population           | 0.096***      |
|                            | (0.016)       |
| Population ages 0–14 years | -0.114***     |
|                            | (0.027)       |
| Tariff rate                | 0.006         |
|                            | (0.005)       |
| Agricultural tax           | -0.018        |
|                            | (0.015)       |
| Agricultural subsidy       | 0.020*        |
|                            | (0.009)       |
| Price level of consumption | 0.005         |
|                            | (0.018)       |
| Public spending on agriculture | 0.015***   |
|                            | (0.004)       |
| Time effects               | Yes           |
| R-squared within           | 0.706         |
| Number of observations     | 300           |

Source: Authors’ estimates.
Notes: * p < 0.10. ** p < 0.05. *** p < 0.01. Standard errors are in parentheses.

We find no effect of agricultural tariff rates on DFS, and do not find any association between the price level of consumption (the PPP for consumption relative to the official exchange rate) and DFS, which might capture implicit taxation of tradable goods and services. However, we do find a small positive association between public spending on agriculture and DFS. Thus there is some evidence that greater public support for agriculture stimulates diversification, although the associations are modest and likely to be heterogeneous. Future research could perhaps consider improved indicators of agricultural development policies, particularly the extent to which such strategies focus on staple foods versus more nutrient-rich foods. However, it might also be the case that policy distortions against nonstaples play less of a role than more structural factors—such as poor transport infrastructure—given that the perishability of nutrient-rich foods is a major barrier to both internal and external trade.
7. CONCLUSIONS

In this paper we set out to systematically explore what drives the diversification of food supplies across countries and regions, and over the course of economic development. We first show that a range of economic theories and evidence predict that food systems should diversify throughout the course of economic growth. Existing economic evidence on DFS and diets is largely confined to the indirect evidence provided by food demand analysis. Income elasticities estimated from such microeconomic studies suggest that diversification into animal-sourced foods and processed foods is more rapid than diversification into fruits, vegetables, and other crop-based foods, while a more macro and more descriptive literature has emphasized and analyzed the diversification of diets and production systems in rapidly transforming economies, particularly in Asia. However, microeconomic theories also predict that agroecological factors condition DFS given the high degree of perishability of many nutrient-rich nonstaple foods, and therefore the limited scope for trade in such foods.

Both our descriptive evidence and our more formal regression models are consistent with these theories. We find strong support for Bennett’s law—DFS is strongly associated with economic growth—but also evidence that other forms of economic transformation drive DFS, notably urbanization and the demographic transition from younger to older populations. This last association is particularly strong. We hypothesize that the transition to an older population structure may influence disposable income at any given per capita level of income, though it may also shift preferences toward tastier and more nutrient-rich foods. Further research should investigate these and other channels.

Yet although economic transformation is clearly a very important driver of diversification, evidence suggests that some countries have unusually undiversified food supplies relative to their development levels. Descriptively, we note that many countries that are major consumers and producers of rice seem to have undiversified food supplies—examples being Bangladesh, Indonesia, Madagascar, Cambodia, and Laos. One explanation may be statistical in nature, particularly if stocks of rice are relatively large in some countries or simply overestimated (for a discussion on the difficulties of estimating rice stocks, see Timmer 2009b). But another explanation may be that these countries share agroecological characteristics that give them a comparative advantage in rice production, and a comparative disadvantage in the production of noncereal foods. Our regression analysis provides some support for this hypothesis, with high population density being strongly negatively associated with DFS. It is not clear why this association exists, however. High population density may be associated with lack of feed for the production of animal-sourced foods—results from our robustness tests support that hypothesis—although high population density may also be associated with abundance of water via either irrigation or rainfall, and there is some evidence that waterlogged soils are a constraint to diversification into fruit and vegetable production. High population density is also a proxy for land availability, however, and it may be that land constraints somehow inhibit diversification out of staples.

This paper is subject to important limitations. It is well known that the FAO food balance sheets provide estimates that have considerable errors, some of which may be systematic in nature. Del Gobbo et al. (2015) compare FAO measures of food supply per capita with household survey–based estimates and find that the FAO measures tend to underpredict consumption of most food groups. We show, however, that the DFS measures do significantly predict a child-level indicator of dietary diversity, even though one would expect variation in this relationship even in the absence of measurement error, simply because child feeding practices may be influenced by cultural norms rather than pure food availability. A second limitation is that our study does not have an experimental design. Rather we focus on testing whether conditional relationships in the data are consistent with economic theory. However, the use of fixed-effects and correlated-random-effects models at least strengthens the rigor of these tests, and rules out obvious sources of confounding.
While these inherent limitations in the quality of the underlying data and in the analytical methods used should not be ignored, it is worth reiterating that the regression analysis provides a series of results that are highly consistent with existing economic theory and evidence. Structural transformation is clearly a fundamental driver of the diversification of food supplies, which may provide one explanation as to why measures of economic growth and urbanization have been robustly associated with lower stunting rates in a wide range of studies (see Bershetyn et al. 2015 for a review).

At the same time, this finding poses many challenges for nutrition strategies, policies, and program design, because it illustrates the difficulties of diversifying food supplies and diets in the absence of prolonged economic growth and transformation. Moreover, while there are many nutrition programs that aspire to accelerate dietary diversification, it is still unclear whether such programs can meaningfully improve diets without sustained growth in incomes (Ruel and Alderman 2013; Pinstrup-Andersen 2013). In addition to behavioral change communications strategies that aim to shift household preferences toward more nutritious foods, an additional strategy would involve using food policies to reduce the real price of nutrient-rich foods. To date, however, little research has assessed how countries might best pursue a strategy of making nutrient-rich foods both more desirable and more affordable, and what impact nutrition-sensitive food policies of that nature might have on diets and various nutrition outcomes. This would appear to be an important agenda for future research.
APPENDIX: SUPPLEMENTARY TABLE

Table A.1 List of countries in the sample

| Country             | Country              |
|---------------------|----------------------|
| Algeria             | Peru                 |
| Argentina           | Philippines          |
| Australia           | Portugal             |
| Austria             | Romania              |
| Bangladesh          | Senegal              |
| Benin               | South Africa         |
| Brazil              | Spain                |
| Bulgaria            | Syrian Arab Republic |
| Cameroon            | Thailand             |
| China               | Tunisia              |
| Costa Rica          | Turkey               |
| Denmark             | Uruguay              |
| Dominican Republic  | Zambia               |
| Ecuador             | Zimbabwe             |
| Finland             |                      |
| France              |                      |
| Gabon               |                      |
| Ghana               |                      |
| Greece              |                      |
| Hungary             |                      |
| India               |                      |
| Indonesia           |                      |
| Ireland             |                      |
| Italy               |                      |
| Jamaica             |                      |
| Japan               |                      |
| Jordan              |                      |
| Kenya               |                      |
| Malaysia            |                      |
| Mexico              |                      |
| Morocco             |                      |
| Nepal               |                      |
| Netherlands         |                      |
| New Zealand         |                      |
| Nicaragua           |                      |
| Panama              |                      |
| Paraguay            |                      |

Source: Authors.

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REFERENCES

Alderman, H., and D. Headey. 2014. The Nutritional Returns to Parental Education. IFPRI Discussion Paper 01379. Washington, DC: International Food Policy Research Institute.

Anderson, K. 2008. Distortions to Agricultural Incentives: A Global Perspective. New York: Palgrave Macmillan and World Bank.

Arimond, M., and M. T. Ruel. 2004. “Dietary Diversity Is Associated with Child Nutritional Status: Evidence from 11 Demographic and Health Surveys.” Journal of Nutrition 134: 2579–2585.

Barro, R. J., and J.-W. Lee. 2010. A New Data Set of Educational Attainment in the World, 1950–2010. NBER Working Paper 15902. Cambridge, MA: National Bureau of Economic Research.

Becker, G. S., and H. G. Lewis. 1973. “On the Interaction between the Quantity and Quality of Children.” Journal of Political Economy 81: S279–S288.

Bennett, M. 1941. “Wheat in National Diets.” Wheat Studies 18: 37–76.

Bershteyn, A., H. M. Lyons, D. Sivam, and N. P. Myhrvold. 2015 “Association between Economic Growth and Early Childhood Nutrition.” Lancet Global Health 3: e79–e80.

Block, S. A. 2004. “Maternal Nutrition Knowledge and the Demand for Micronutrient-Rich Foods: Evidence from Indonesia.” Journal of Development Studies 40: 82–105.

Bloom, D. E., and J. G. Williamson. 1998. “Demographic Transitions and Economic Miracles in Emerging Asia.” World Bank Economic Review 12: 419–455.

Boserup, E. 1965. The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure. London: Allen and Unwin.

Bouis, H., L. Haddad, and E. Kennedy. 1992. “Does It Matter How We Survey Demand for Food? Evidence from Kenya and the Philippines.” Food Policy 17: 349–360.

Carletto, G., M. Ruel, P. Winters, and A. Zezza. 2015. “Farm-Level Pathways to Improved Nutritional-Status: Introduction to the Special Issue.” Journal of Development Studies 51: 945–957.

Chamberlain, Gary. 1984. “Panel Data” In, Handbook of Econometrics, Edition 1, Volume 2, 1247–1318, edited by Z. Griliches and M. D. Intriligator. Amsterdam: Elsevier.

Cohen, D., and M. Soto. 2007. “Growth and Human Capital: Good Data, Good Results.” Journal of Economic Growth 12: 51–76.

Cunningham, K. 2009. Rural and Urban Linkages: Operation Flood’s Role in India’s Dairy Development. IFPRI Discussion Paper 00924. Washington DC: International Food Policy Research Institute.

de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. “Peasant Household Behavior with Missing Markets: Some Paradoxes Explained.” Economic Journal 101: 1400–1417.

Del Gobbo, L. C., S. Khatibzadeh, F. Imamura, R. Micha, P. Shi, M. Smith, S. S. Myers, and D. Mozaffarian. 2015. “Assessing Global Dietary Habits: A Comparison of National Estimates from the FAO and the Global Dietary Database.” American Journal of Clinical Nutrition 101: 1038–1046.

DHS (Demographic and Health Surveys Program). 2016. STATcompiler. Calverton, MD: ICF International and US Agency for International Development.

Ecker, O., and M. Qaim. 2011. “Analyzing Nutritional Impacts of Policies: An Empirical Study for Malawi.” World Development 39: 412–428.

Falkinger, J., and J. Zweimüller. 1996. “The Cross-Country Engel Curve for Product Diversification.” Structural Change and Economic Dynamics 7: 79–97.

Fan, Y., H. Li, and G. Miguelz-Macho. 2013. “Global Patterns of Groundwater Table Depth.” Science 339: 940–943.

FAO (Food and Agriculture Organization of the United Nations). 2016. Food Security Indicators. Rome.

Electronic copy available at: https://ssrn.com/abstract=2884935
Foote, J. A., S. P. Murphy, L. R. Wilkens, P. P. Basiotis, and A. Carlson. 2004. “Dietary Variety Increases the Probability of Nutrient Adequacy among Adults.” *Journal of Nutrition* 134: 1779–1785.

Graham, I. D., and J. Tetroe. 2007. “CIHR Research: How to Translate Health Research Knowledge into Effective Healthcare Action.” *Healthcare Quarterly* 10: 20–22.

Hatloy, A., L. Torheim, and A. Oshaug. 1998. “Food Variety: A Good Indicator of Nutritional Adequacy of the Diet? A Case Study from an Urban Area in Mali, West Africa.” *European Journal of Clinical Nutrition* 52: 891–898.

Headey, D. 2013. *The Global Landscape of Poverty, Food Insecurity, and Malnutrition, and Its Implications for Agricultural Development Strategies.* IFPRI Discussion Paper 01303. Washington, DC: International Food Policy Research Institute.

Headey, D., and O. Ecker. 2013. “Rethinking the Measurement of Food Security: From First Principles to Best Practice.” *Food Security* 5: 327–343.

Headey, D., and J. Hoddinott. 2016. “Agriculture, Nutrition, and the Green Revolution in Bangladesh.” *Agricultural Systems* 149: 122–131.

Hoppe, C., C. Molgaard, and K. F. Michaelsen. 2006. “Cow’s Milk and Linear Growth in Industrialized and Developing Countries.” *Annual Review of Nutrition* 26: 131–173.

Iannotti, L. L., C. K. Lutter, D. A. Bunn, and C. P. Stewart. 2014. “Eggs: The Uncracked Potential for Improving Maternal and Young Child Nutrition among the World’s Poor.” *Nutrition Reviews* 72: 355–368.

Iannotti, L., E. Muehlhoff, and D. McMahon. 2013. “Review of Milk and Dairy Programmes Affecting Nutrition.” *Journal of Development Effectiveness* 5: 82–115.

Jensen, R. T., and N. H. Miller. 2010. *A Revealed Preference Approach to Measuring Hunger and Undernutrition.* NBER Working Paper 16555. Cambridge, MA: National Bureau of Economic Research.

Kant, A. K., A. Schatzkin, T. B. Harris, R. G. Ziegler, and G. Block. 1993. “Dietary Diversity and Subsequent Mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-Up Study.” *American Journal of Clinical Nutrition* 57: 434–440.

Kumar, P., A. Kumar, S. Parappurathu, and S. Raju. 2011. “Estimation of Demand Elasticity for Food Commodities in India.” *Agricultural Economics Research Review* 24: 1–14.

Levi, F., C. Pasche, C. La Vecchia, F. Lucchini, and S. Franceschi. 1999. “Food Groups and Colorectal Cancer Risk.” *British Journal of Cancer* 79: 1283.

Logan, T. D. 2006. “Nutrition and Well-Being in the Late Nineteenth Century.” *Journal of Economic History* 66: 313–341.

Masters, W. A., A. Hall, E. Martinez, P. Shi, G. Singh, P. Webb, and D. Mozaffarian. Forthcoming. “The Nutrition Transition and Agricultural Transformation: A Preston Curve Approach.” *Agricultural Economics.*

Melo, P. C., Y. Abdul-Salam, D. Roberts, A. Gilbert, R. Matthews, L. Colen, S. Mary, and S. Gomez Y Paloma. 2015. *Income Elasticities of Food Demand in Africa: A Meta-Analysis.* Brussels: Joint Research Center of the European Union. http://publications.jrc.ec.europa.eu/repository/handle/JRC98812.

Minten, B., D. Stifel, and S. Tamru. 2014. *Structural Transformation in Ethiopia: Evidence from Cereal Markets.* ESSP Working Paper 39. Addis Ababa: Ethiopia Strategy Support Program of the International Food Policy Research Institute. https://ideas.repec.org/p/fpr/esswp/39.html.

Moursi, M. M., M. Arimond, K. G. Dewey, S., Trèche, M. T. Ruel, and F. Delpeuch. 2008. “Dietary Diversity Is a Good Predictor of the Micronutrient Density of the Diet of 6- to 23-month-old Children in Madagascar.” *Journal of Nutrition* 138: 2448–2453.

Muhammad, A., J. L. Seale, B. Meade, and A. Regmi. 2011. *International Evidence on Food Consumption Patterns: An Update Using 2005 International Comparison Program Data.* USDA-ERS Technical Bulletin 120502. Washington, DC: Economic Research Services of the United States Department of Agriculture.

Mundlak, Y. 1978. “On the Pooling of Time Series and Cross Section Data.” *Econometrica* 46: 69–85.
Murphy, S., and L. Allen. 2003. “Nutritional Importance of Animal Source Foods.” *Journal of Nutrition* 133: 3932s–3935s.

Pingali, P. 2007. “Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy.” *Food Policy* 32: 281–298.

Pingali, P., Y. Bigot, and H. Binswanger. 1987. *Agricultural Mechanisation and the Evolution of Farming Systems in Sub-Saharan Africa.* Washington, DC: John Hopkins University Press and World Bank.

Pingali, P. 2007. “Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy.” *Food Policy* 32: 281–298.

Reardon, T., and P. Timmer. 2012. “The Economics of the Food System Revolution.” *Annual Review of Resource Economics* 4: 225–264.

Regmi, A. 2001. “Changing Structure of Global Food Consumption and Trade: An Introduction.” In *Changing Structure of Global Food Consumption and Trade,* WRS-01-1, edited by A. Regmi. Washington, DC: Economic Research Service of the US Department of Agriculture.

Remans, R., S. A. Wood, N. Saha, T. L. Anderman, and R. S. DeFries. 2014. “Measuring Nutritional Diversity of National Food Supplies.” *Global Food Security* 3: 174–182.

Ruel, M. T., and H. Alderman. 2013. “Nutrition-Sensitive Interventions and Programmes: How Can They Help to Accelerate Progress in Improving Maternal and Child Nutrition?” *Lancet* 382: 536–551.

Seale, J. L., A. Regmi, and J. Bernstein. 2003. *International Evidence on Food Consumption Patterns.* Washington, DC: Economic Research Service of the US Department of Agriculture.

Shimbo, S., K. Kimura, Y. Imai, M. Yasumoto, K. Yamamoto, S. Kawamura, T. Watanabe, O. Iwami, H. Nakatsu, and M. Ikeda. 1994. “Number of Food Items as an Indicator of Nutrient Intake.” *Ecology of Food and Nutrition* 32: 197–206.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural Household Models: Extension, Application, and Policy.* Baltimore: Johns Hopkins University Press.

Skoufias, E. 2003. “Is the Calorie–Income Elasticity Sensitive to Price Changes? Evidence from Indonesia.” *World Development* 31: 1291–1307.

Slattery, M. L., T. D. Berry, J. Potter, and B. Caan. 1997. “Diet Diversity, Diet Composition, and Risk of Colon Cancer (United States).” *Cancer Causes and Control* 8: 872–882.

Steyn, N., J. Nel, G. Nantel, G. Kennedy, and D. Labadarios. 2006. “Food Variety and Dietary Diversity Scores in Children: Are They Good Indicators of Dietary Adequacy?” *Public Health Nutrition* 9: 644–650.

Subramanian, S., and A. Deaton. 1996. “The Demand for Food and Calories.” *Journal of Political Economy* 104: 133–162.

Theil, H., and R. Finke. 1983. “The Consumer’s Demand for Diversity.” *European Economic Review* 23: 395–400.

Timmer, C. P. 2009a. *A World without Agriculture: The Structural Transformation in Historical Perspective (Henry Wendt Lecture).* Washington, DC: American Enterprise Institute.

———. 2009b. *Did Speculation Affect World Rice Prices?* ESA Working Paper 09-07. Rome: Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations.

Timmer, C. P., W. P. Falcon, and S. R. Pearson. 1983. *Food Policy Analysis.* Washington, DC: World Bank.

Tiwari, S., E. Skoufias, and M. Sherpa. 2013. *Shorter, Cheaper, Quicker, Better: Linking Measures of Household Food Security to Nutritional Outcomes in Bangladesh, Nepal, Pakistan, Uganda, and Tanzania.* Policy Research Working Paper 6584. Washington, DC: World Bank. http://ideas.repec.org/p/wbk/wbrwps/6584.html.

UNICEF. 1990. *Strategy for Improved Nutrition of Children and Women in Developing Countries.* Geneva.

Webb, P., and S. A. Block. 2004. “Nutrition Information and Formal Schooling as Inputs to Child Nutrition.” *Economic Development and Cultural Change* 52: 801–820.
WorldClim. 2016. Global Climate Data. Accessed May 22, 2016. http://worldclim.org/.

World Bank. 2009. World Development Report 2009: Reshaping Economic Geography. Washington, DC.
———. 2016. World Development Indicators Online. Washington, DC. http://data.worldbank.org/data-catalog/world-development-indicators.

Yu, X., and D. Abler. 2009. “The Demand for Food Quality in Rural China.” American Journal of Agricultural Economics 91: 57–69.

Yu, X., Z. Gao, and Y. Zeng. 2014. “Willingness to Pay for the ‘Green Food’ in China.” Food Policy 45: 80–87.
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