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Article

Caloric Intake and Energy Expenditures in India

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Abstract

Total energy expenditures for the Indian population between 1983 and 2012 are estimated to shed light on the debate concerning falling measured caloric intake during the period (A. Deaton and J. Drèze. 2009. "Food and Nutrition in India: Facts and Interpretations." *Economic and Political Weekly* 44(7): 42–65). Anthropometric, time-use, and detailed employment surveys are used to estimate the separate components of total energy expenditure related to metabolism and physical activity levels. Despite a significant drop in adult physical activity levels, total energy expenditures are flat overall between 1983 and 2012. Rising metabolic requirements due to increases in weight dampened the effect of falling activity levels on total energy expenditure. In addition, the 10 percent decline in the population share of children in the period raised average total energy expenditures considerably as children have much lower metabolic requirements and activity levels than adults.

JEL classification: D12, I31, I32, O12, O15

Keywords: India, calories, energy, expenditure, activity

1. Introduction

Caloric intake and food expenditures are often viewed as key indicators of an individual's ability to satisfy the most basic of needs and as good predictors of net nutritional outcomes, which has made these indicators fundamental to the measurement of household welfare since the work of Engel (1895). Applications include the construction of India's national poverty measures, guided by household caloric "norms" of 2,400 calories per day in rural areas and 2,100 in urban areas, as well as equivalence scales (Barten 1964; Deaton and Muellbauer 1986). In this context, Deaton and Drèze (2009) note the puzzling finding that based on India's National Sample Survey (NSS), per capita caloric intake in India fell substantially between 1983 and 2005 despite rising per capita expenditures. They consider explanations, ranging from measurement error in consumption data to consumer-driven changes (due to tastes, prices, or changes in the set of available goods), to changes in physical activity levels and the disease environment, that may have lowered the demand for calories, but reach no firm conclusion.[1]

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[1] Note that the "puzzle" documented by Deaton and Drèze (2009) for India has also been documented in other contexts, e.g., Du et al. (2002) for China and Clark, Hubermand, and Lindert (1995) for Great Britain during the Industrial Revolution. Literature on measurement error and the disease environment in the Indian context are discussed below.

This article presents estimates of total energy expenditures (TEEs) for the Indian population over the 1983–2012 period to provide insight into this puzzling finding. TEEs are the total calories required for maintaining one's weight level given the body's metabolic processes and physical activity levels. Anthropometric data from three waves of India's National Family Health Survey (NFHS) (1998, 2005, 2015) are used to estimate resting energy expenditures (REE) that capture metabolic requirements related to height, weight, age, and gender for individuals at rest. Detailed time-use data from India's 1998–1999 Time-Use Survey (TUS), matched to activity factors in FAO/WHO/UNU Expert Consultation (2001), are used to estimate activity levels (AL) that capture the additional energy used for physically intensive activities. The large set of variables in common between these surveys and the NSS employment surveys (Schedule 10) that were conducted between 1983 and 2012 are used to estimate individual TEE. This quantification provides insight into the evolution of population TEE and the contributions of changes in demographics, occupation and industry, work status, and labor-intensive domestic tasks.

The main finding is that population-level TEE in India is fairly flat between 1983 and 2012 and actually increased slightly over the 1983 to 2005 period before declining slightly between 2005 and 2012. The quantification highlights two reasons for flat TEE over time. First, individual and household characteristics that predict lower ALs also tend to predict higher REEs for a given demographic composition. For example, higher levels of education, higher levels of expenditure, and less labor-intensive occupations are all associated with lower AL but higher REE. Because TEE is computed as the product of REE and AL (FAO/WHO/UNU Expert Consultation 2001), as discussed later, the effect of changes in education, expenditures, and occupation on TEE tends to be smaller than their effect on AL. Overall, AL fell and REE increased over this period controlling for demographic composition. The analysis also uncovers evidence of household scale economies in TEE. Households with more members, but similar demographic composition and per capita expenditures, have a lower AL that is only partly offset by higher REE. Although household scale economies contribute little to the main findings on population TEE, this supports the conjecture in Deaton and Paxson (1998) that "caloric overheads" (fixed costs of common household activities in developing countries, such as travel for work, buying/selling goods, or collection of water or fuel) could explain the common empirical finding that larger households have lower per capita food expenditures holding constant demographic composition and per capita expenditures.

Second, the estimates imply that TEE fell by over 100 calories per day over this period for individuals aged 15 or older, which on its own would be enough to account for most of the decline in caloric intake in NSS data during this period. However, over the 1983–2012 period, India underwent substantial demographic change, with the share of the population aged 14 and under falling from 40 percent to 30 percent. Children have much (about 40 percent) lower TEE than adults, due to both lower REE (due to smaller size) and lower AL (particularly in rural areas where primary/middle-school attendance appears much less physically active than adult activities). Thus even though TEE is falling for both adults and (to a lesser extent) children throughout this period, demographic change at the population level is more than enough to offset this "within" effect, except after 2005 when ALs fell particularly quickly.

The findings of flat population TEE and modest gains in nutritional status over time are discussed in light of the potential contribution of measurement error and changes in the disease environment to the Deaton and Drèze (2009) puzzle of declining measured caloric intake. Smith (2015) argues that the NSS estimates of caloric intake may be biased down, especially in recent years, due to rising consumption of food away from home.[2] Evidence on the magnitude of recall bias identified using different survey recall

Other contributions include Basole and Basu (2015), who focus on the role of prices and food budgets squeezed by rising expenditures on fuel, education, and medical goods, Patnaik (2010), who argues that higher relative prices for food lowered demand, and Gupta (2013), who argues that conspicuous consumption (Veblen goods) could explain lower food intake.

[2] See also Fiedler and Yadav (2017) for evidence from the 2011–2012 NSS survey and Smith, Dupriez, and Troubat (2014) for a general review of the reliability of food data collected in consumption and expenditure surveys.

periods (National Sample Survey Organization 2000; NSSO 2013) and the sensitivity of estimated caloric intake to assumptions about the caloric value of food expenditures is reviewed. The findings are also discussed in the context of Duh and Spears (2017), who test one of the potential mechanisms discussed in Deaton and Drèze (2009). Duh and Spears (2017) show that infant mortality and other indicators of disease related to nutritional absorption (e.g., latrine ownership, diarrhea, and open defecation) are strongly associated with within-district changes in NSS caloric intake between 1988 and 2005 as well as in the cross-section. They find that this pattern holds even when controlling for household and individual variables that capture much of the variation in TEE explored in this paper, concluding that an improved disease environment can account for a substantial decline in caloric intake in India because households "lose" fewer calories to disease and therefore choose to consumer fewer calories. Relative to their work, this article tests a different potential mechanism discussed in Deaton and Drèze (2009), using the most detailed available data on physical activity and physical size to directly quantify TEE. Overall, the finding that TEE is fairly flat over the 1983–2012 period, combined with the evidence on modest gains in nutritional status, suggests that most of the decline in NSS caloric intake is a result of measurement error and lower caloric burden of disease rather than large decreases in population TEE.

The paper is organized as follows: the next section ("Data and measurement") describes the data and methodology used for estimating total energy expenditure and discusses some important sources of variation across households, the following section ("Estimates of TEE") presents results for changes in total energy expenditure over time and discusses the broader context of changes in caloric intake measured in the NSS, and the last section offers concluding comments and suggestions for future research.

2. Data and Measurement of Components of TEE

This section briefly outlines the methodology and data used to measure TEE from household data sets. The appendix contains a more detailed description including robustness to alternative assumptions. TEE measures the amount of energy used by the human body during a given period. When TEE equals caloric intake there is no weight gain or loss. A standard method to calculate TEE is the factorial method described in FAO/WHO/UNU Expert Consultation (2001). Indian Council of Medical Research (2009) uses this method to estimate prescriptive caloric requirements for Indian households, based on the 95th percentile height and weight observed in rural areas and providing recommended daily caloric intakes for sedentary, light, moderate, and heavy physical activity. The factorial method can be used to generate descriptive estimates of population-level TEE using the height, weight, demography, and ALs observed in the Indian population using various data sources. The factorial method computes TEE for individual i using

$$\mathrm{TEE}_i = \mathrm{REE}_i * \mathrm{AL}_i,$$

where i is an individual, REE_i is the REE of individual i, and AL_i represents the AL of individual i. REE makes up the bulk of TEE (about two-thirds for the average person) and reflects the energy required for essential metabolic functions. An individual in a complete state of rest has AL = 1, TEE = REE, and still needs a lot of calories to avoid weight loss.[3] An individual that does more than rest will have an AL greater than 1. The factorial method implies that a given reduction in AL generates a larger reduction in TEE for individuals with larger REE. Thus, when estimating levels or changes in TEE for a population, one cannot simply average AL or REE across individuals but must sum the individual TEE as constructed above. Measurement of these two components for the Indian population is discussed next.

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[3] Basal energy expenditure (BEE) is closely related to REE. Measuring BEE requires a minimum period of fasting before testing and is lower than REE, which incorporates the energy cost of metabolizing food. Most laboratory measures use REE. It is possible to directly quantify the energy cost of metabolizing different macronutrients but the differences over time and across households appear minimal.

Table 1. Daily Resting Energy Expenditure and Activity Level Estimates

Panel A: REE (calories/day) from NFHS	Ever-married women 15–49	Women 15–49	Men 15–54	Children 0–3
1998 (NFHS-2)	1,128	—	—	502
1998 rural	1,114	—	—	499
1998 urban	1,169	—	—	513
2005 (NFHS-3)	1,145	1,140	1,496	492
2005 rural	1,126	1,122	1,471	485
2005 urban	1,189	1,177	1,542	517
2015 (NFHS-4)	1,180	1,169	1,531	514
2015 rural	1,161	1,151	1,510	507
2015 urban	1,221	1,205	1,570	532
Panel B: AL (rest=1) from TUS	**Men 15+**	**Women 15+**	**Boys 6–14**	**Girls 6–14**
1998–99 mean	1.93	1.89	1.49	1.51
1998–1999 SD	0.47	0.34	0.23	0.23
1998–99 rural mean	2.03	1.96	1.50	1.53
1998–99 urban mean	1.69	1.71	1.47	1.46

Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey (TUS) and the National Family Health Survey (NFHS) rounds 2, 3, and 4.
Note: REE is resting energy expenditure and AL is activity level. Panel A is based on applying the equations in Henry (2005) to heights and weights reported in NFHS. Panel B is based on using the matched activity factors from FAO/WHO/UNU Expert Consultation (2001) and activities reported in the TUS (see table S1.2 in the supplementary online appendix). Reported values are population statistics using survey sampling weights.

REE

Although REE can be directly measured only in a laboratory setting, there are numerous published predictive equations that are determined by regressing measured REE on more commonly observed attributes such as age, sex, height, and weight. While these equations miss an important idiosyncratic element of metabolism, they typically yield an R^2 over 0.7. The equations provided in Henry (2005) are used here—these are based on regressing REE on height and weight separately by sex and age groups (1–3, 4–9, 10–17, 18–30, 31–60, 60+) for a large population of individuals drawn from around the world, including tropical and developing countries.

The anthropometric micro-data used come from India's NFHS, a household survey that measures height and weight for a subset of the Indian population. Eligibility for anthropometric measurement within sampled households varies by year—in 1998, children under 3 and ever-married women aged 15–49 were measured, while in 2005 and 2015 all children under 5, all women aged 15–49, and a random subsample of men aged 15–54 were measured. The results of applying the Henry (2005) equation are reported in the first panel of table 1.[4] As discussed in Appendix A, data generated by the National Nutritional Monitoring Bureau (reported in Indian Council of Medical Research 2009) provide additional measurement of height and weight by age for rural areas of 16 Indian states in 2000–2002 to extrapolate outside the age range in the NFHS. The NFHS estimates shown in table 1 highlight three facts that will be important later: (a) adult men have higher REE than adult women, who have higher REE than children, (b) REE is higher in urban than rural areas as urban individuals are slightly taller and substantially heavier for a given age/sex, and (c) REE has been increasing over time for a given age and sex, mostly due to increasing weight (see table S1.1 in the supplementary online appendix).

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[4] Validation studies by Shetty, Soares, and Sheela (1986) and Ferro-Luzzi et al. (1997) find that these types of prediction equations, which are typically estimated on European-descended populations, have a reasonably good fit for subjects in India.

ALs

ALs are estimated by aggregating up from the most detailed activity data available. With data on the share of time allocated across J different activities, an estimate of individual i's AL is

$$\mathrm{AL}_i = \sum_{j=1}^{J} \mathrm{Share}_{ij} * \mathrm{AF}_j,$$

where Share_{ij} is the fraction of individual i's time spent on activity j. The term AF_j is an activity factor for activity j that measures the intensity of activity j relative to rest (equal to 1). Individual AL are thus weighted averages of activity factors where the weights vary across individuals based on their time use.

The most detailed activity data for India come from the TUS conducted in 1998–1999 by the National Sample Survey Organization for six states (Gujarat, Haryana, Madhya Pradesh, Meghalaya, Orissa, and Tamil Nadu) that make up 25 percent of India's population and are close to representative in terms of regional variation. These data cover all individuals aged 6 or older from the sampled households. Individuals report their activities, classified into 154 activities (see table S1.2 in the supplementary online appendix), in 20-minute increments based on a 24-hour recall period, with variant days capturing weekends/market days. FAO/WHO/UNU Expert Consultation (2001) reports activity factors (derived from field measurement) for a long list of activities that are common in developing countries. Each activity in the TUS can be matched to an activity factor, with some adjustments to deal with codes that have no obvious match (e.g., "other" categories and travel), discussed in Appendix B.

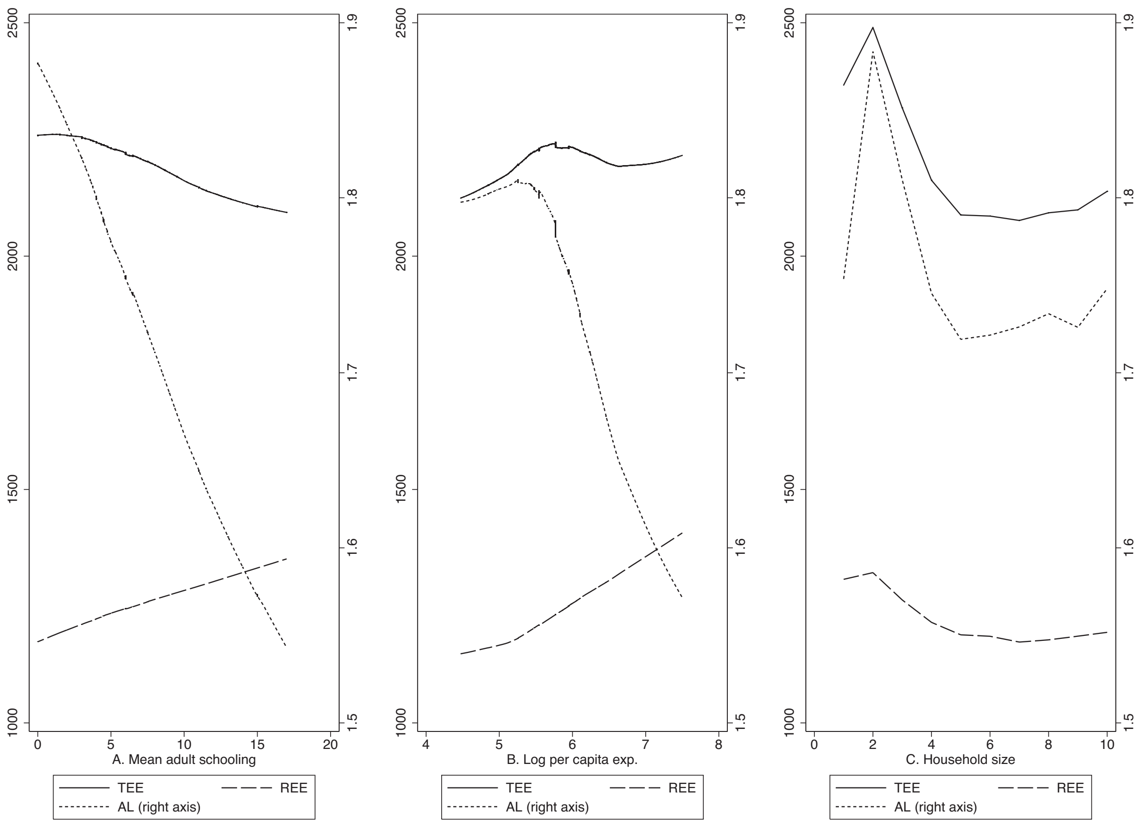
Panel B of table 1 reports estimates of activity levels separately by rural and urban residence, sex, and two age groups (6–14, 15 and over) for individuals in the TUS. The data indicate that rural activity levels are substantially higher than urban levels, with the average rural–urban gap equal to about 75 percent of the population standard deviation for adults. The rural–urban gap is considerably smaller for children, and children in general have much lower ALs than adults, reflecting the relatively low ALs associated with school attendance. A literature review identified only two studies that directly estimate activity levels in India, by directly measuring REE and TEE for tiny samples of "free-living" adults. The estimates here are in line with those reported in Borgonha, Shetty, and Kurpad (2000), who find an AL of 1.9 for rural men near Bangalore, and Krishnaveni et al. (2009), who find an average AL of 1.45 for boys and girls aged 8 to 9 in Mysore.

Imputation of TEE to NSS Data

As REE and AL cannot be directly estimated for the same data set using the factorial method, and the coverage in terms of age, state, and time period of the NFHS and TUS is incomplete, the estimates of TEE over time-use NSS data that are representative at the population level. This is done using the large number of common variables between the NFHS, TUS, and NSS Schedule 10 employment survey (hereafter NSS-E). Predictive equations for REE or AL are first estimated using the NFHS or TUS and the large set of individual and household variables in common with the NSS-E, and these predictive equations are then used to generate $\widehat{\mathrm{TEE}_i} = \widehat{\mathrm{REE}_i} * \widehat{\mathrm{AL}_i}$ for each individual in the NSS-E. The analysis here focuses on the "thick" NSS-E survey rounds beginning with the oldest available (1983) through to the most recently available (2011–2012).

A detailed discussion of this procedure can be found in Appendix B. Depending on the data set (NFHS or TUS) these variables include individual and household demographics, education levels, two-digit occupation and industry codes at the household and/or individual level, work status (school, domestic work, casual versus salary versus self-employment), labor-intensive "domestic" tasks typically carried out by females not in the labor force (e.g., collecting firewood or water, husking paddy, and grinding grains), labor-intensive agricultural tasks, land possessed, and total expenditures deflated using an all-India Consumer Price Index (see supplementary online appendix tables S1.3 and S1.4). When restricting estimation

Figure 1. Household Total Energy Expenditure Varies with Education, Expenditure and Household Size in the Cross-Section



Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey and the National Family Health Survey rounds 2, 3, and 4.

Note: Unconditional relationship between household total energy expenditure (TEE) (daily per person) and mean years of education for members over 18, log per capita expenditure (dropping observations in the 1 percent left and right tails), and household size (up to size 10) in the 1998–1999 Time-Use Survey (TUS) cross-section. Activity level (AL) is measured directly and resting energy expenditure (REE) is imputed using the National Family Health Survey (see text for description). Each observation represents a household average. Note that 92 percent of households are between 2 and 8 members.

to the six states in the TUS, state fixed effects are also included. The R^2 from these predictive equations ranges from 0.14 to 0.35 for the NFHS REE estimates and from 0.37 to 0.63 for the TUS AL estimates, suggesting the variables in common with the NSS-E are rich enough to capture a lot of the sample variation in REE and AL from the other data sets. The estimation procedure here is adequate for estimation population or conditional means, which is the goal here, but it would need to be amended if one were interested in the variance or other moments of the distribution (e.g., fraction of households with TEE below some threshold).

Analysis of Household Characteristics

While table 1 makes it clear that demographic composition and rural/urban location will generate large differences in TEE (and its REE and AL components) across households, there is also considerable cross-sectional variation related to other variables. Before turning to estimates of population TEE over time, some interesting cross-sectional patterns are discussed to demonstrate the richness of these data. For this analysis, only the 1998–1999 TUS and REE imputation procedure are used.

Table 2. Household Total Energy Expenditure and Household Characteristics

Dependent variable (logs)	TEE	REE	AL	TEE	REE	AL	Cal	Cal
Household sizes	All	All	All	2–8	2–8	2–8	All	2–8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean school	-0.004^{***}	0.006^{***}	-0.009^{***}	-0.004^{***}	0.006^{***}	-0.009^{***}	-0.008^{***}	-0.007^{***}
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Log exp. p.c.	-0.010^{*}	0.002	-0.011^{**}	-0.013^{**}	0.002^{**}	-0.014^{***}	0.440^{***}	0.432^{***}
	(0.005)	(0.001)	(0.004)	(0.006)	(0.001)	(0.004)	(0.014)	(0.016)
Log hh size	0.003	0.014^{***}	-0.012^{**}	-0.017^{**}	0.016^{***}	-0.033^{***}	-0.015^{**}	-0.029^{***}
	(0.007)	(0.002)	(0.005)	(0.006)	(0.001)	(0.006)	(0.006)	(0.009)
Observations	18,528	18,528	18,528	17,013	17,013	17,013	28,248	24,908
R-squared	0.668	0.922	0.502	0.692	0.940	0.528	0.394	0.372

Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey, the National Family Health Survey rounds 2, 3, and 4, and the National Sample Survey round 50 (1993–94, six Time-Use Survey states only).

Note: Dependent variable (in logs) is household total energy expenditure (TEE), resting energy expenditure (REE), activity level (AL), caloric intake (Cal) per capita, household (hh), or expenditure per capita (exp.p.c.). Standard errors in parentheses clustered by state/sector. Controls include demographic ratios (male/female aged 0–2, 3–5, 6–9, 10–14, 15–17, 18–59, 60+), Scheduled Caste/Scheduled Tribe status, religion, and sector by state dummies. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 1 plots household TEE (averaged across individuals within the household) against mean years of schooling for members aged 18 and up, monthly per capita expenditures, and household size. Panel A shows that TEE declines in years of schooling, a net effect that combines a sharper decline in AL and a partly offsetting rise in REE. Panel B shows a similar pattern for per capita expenditures, except that in this AL rises with per capita expenditure for the poorest households, likely reflecting a combination of unemployment/underemployment for the poorest households and a higher proportion of non-earning children. TEE is falling in household size, particularly in the range of 2 to 6 members, which is mostly driven by lower AL, although the unconditional relationship in Figure 1 partly reflects demographic composition.

The finding that TEE is falling in household size is notable given the observation by Deaton and Paxson (1998) that for several developing countries, measured food expenditure per capita declines in household size. A similar pattern holds for measured caloric intake. Deaton and Paxson (1998) argue that this is a "puzzle" in the sense that larger households with a given demographic composition should benefit from economies of scale that increase their per capita consumption of relatively private/rival goods like food. They suggest that "caloric overheads"—energy expenditures that need to be incurred by only one household member on behalf of the entire household—could be one possible explanation. The TUS data are rich enough to capture differences in time spent on domestic chores, travel, etc. that would be hard to detect in most household surveys.

To examine this further and also to control for demographic composition, table 2 estimates a log-log regression specification similar to the one used by Deaton and Paxson (1998). The dependent variable is log household average TEE, REE, or AL. Detailed demographic controls for age/sex ratios, log household size, log per capita expenditures, and mean years of adult education are included. When including all household sizes (1–14), there is close to a zero partial elasticity of TEE to household size, resulting from a perfect offset of REE and AL. Larger households economize on energy, but their members are also physically "larger" on average. When restricting to household sizes between 2 and 8, which make up 92 percent of the sample, there is a significant negative partial elasticity of about 0.017, due to a negative effect on AL that is much larger than the positive effect on REE. Both expenditure and education reduce TEE holding constant demographics and appear to have independent effects.

Columns 7 and 8 of table 2 estimate the same specification but replace TEE with caloric intake estimated for the 1993–94 NSS 50th round Schedule 1 (consumption survey) in the same states (see Appendix C). The coefficient is similar in magnitude (−0.029 using households sized 2 to 8) suggesting that scale economies in energy expenditures can potentially explain much of the apparent decline in caloric

Table 3. Estimates of Daily Total Energy Expenditure and Its Components over Time

	Population			Males 15+		Females 15+		Under age 15		
Year	TEE (1)	REE (2)	AL (3)	TEE (4)	AL (5)	TEE (6)	AL (7)	TEE (8)	AL (9)	Population share (10)
					All-India mean					
1983	2,136	1,179	1.77	2,864	1.95	2,244	1.93	1,499	1.52	0.40
1988	2,134	1,186	1.77	2,858	1.94	2,234	1.92	1,475	1.50	0.39
1994	2,158	1,200	1.77	2,855	1.93	2,241	1.91	1,463	1.49	0.36
2000	2,155	1,210	1.75	2,829	1.91	2,225	1.89	1,477	1.48	0.36
2005	2,172	1,222	1.75	2,825	1.90	2,215	1.88	1,476	1.47	0.34
2009	2,159	1,243	1.72	2,753	1.85	2,182	1.83	1,460	1.44	0.31
2012	2,153	1,250	1.70	2,729	1.83	2,158	1.81	1,469	1.44	0.30
					Rural sector mean					
1983	2,168	1,165	1.81	2,959	2.04	2,290	1.99	1,505	1.53	0.41
1994	2,190	1,183	1.81	2,951	2.02	2,289	1.97	1,458	1.49	0.37
2000	2,184	1,191	1.79	2,930	2.00	2,275	1.96	1,472	1.48	0.37
2005	2,199	1,201	1.79	2,930	2.00	2,264	1.94	1,469	1.47	0.35
2012	2,179	1,230	1.74	2,828	1.92	2,197	1.86	1,455	1.43	0.31
					TUS state mean					
1983	2,152	1,183	1.78	2,864	1.95	2,280	1.95	1,490	1.51	0.39
1994	2,184	1,204	1.78	2,857	1.94	2,281	1.94	1,454	1.48	0.35
2000	2,190	1,214	1.77	2,847	1.93	2,264	1.92	1,462	1.47	0.34
2005	2,208	1,224	1.77	2,847	1.93	2,260	1.91	1,468	1.47	0.32
2012	2,199	1,254	1.73	2,776	1.87	2,196	1.83	1,452	1.42	0.28

Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey, the National Family Health Survey rounds 2, 3, and 4, and the National Sample Survey rounds 38, 43, 50, 55, 61, 66, and 68.

Note: TEE is total energy expenditure, REE is resting energy expenditure, and AL is activity level. Columns 1–3 report population means (using sampling weights). Columns 4–9 are population means for subsets of the population. Column 10 is the share of the children aged 14 and under in the population. The reported years correspond to the last year covered by National Sample Survey "thick" survey rounds (38, 43, 50, 55, 61, 66, 68).

intake with household size.[5] Note that the coefficient on education has a similar negative coefficient for caloric intake as for TEE, but per capita expenditures only has a large positive coefficient for caloric intake.

The patterns documented here in the cross-section foreshadow one of the main findings in the time series, which is that REE often moves in the opposite direction to AL in terms of covariance with observable household characteristics. This dampens the effect of changes in these characteristics on changes in TEE. Figure S1.1 in the supplementary online appendix shows that this pattern also occurs across household main industry—households headed by agricultural or construction workers have the highest activity levels in India but also have the lowest REE.

3. Estimates of TEE over 1983–2012

Population Estimates

Table 3 presents estimates of population average TEE for India between 1983 and 2012. Three separate panels present results for all India, rural India only, and for the six states in the TUS only. The first column

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[5] The decline is "apparent" because Gibson (2002) and Gibson and Kim (2007) show that much of the puzzling decline first documented in Deaton and Paxson (1998) is reduced when using survey instruments less subject to recall errors, implying that a substantial part of the measured decline in most household surveys is simply measurement error that is negatively correlated with household size. However, they still find some "real" decline in caloric intake with household size when using the alternative survey instruments. See also Beegle et al. (2012) and Brzozowski, Crossley, and Winter (2017) for more evidence on measurement error in food-consumption surveys, correlated with household size.

reports the survey-weighted population average TEE expressed in calories per day. TEE is fairly flat over the entire 1983–2012 period, rising by only 0.8 percent. There is a small increase over the 1988–1994 and 2000–2005 periods, and a small decrease from 2005 to 2012, but these changes are small relative to plausible measurement and estimation errors. Column 2 presents the population average REE which rose by 6 percent throughout the 1983–2012 period. Column 3 presents the population average AL which fell throughout the 1983–2012 period by about 4 percent, mostly after 2005.

Recall that the product of population average REE and AL is not population average TEE, and that changes in population AL and REE capture both changes within age/sex demographic groups and changes in the demographic composition of the population. Estimates are reported separately for population TEE and AL for males 15 and over (columns 4–5), females 15 and over (columns 6–7), and children aged 14 and below (columns 8–9). TEE declined substantially for adult men (135 calories) and women (86 calories) over the 1983–2012 period but by less for children (30 calories). Activity levels for adult men and women fell over 6 percent, and these decreases were only partly offset by their rising REE. For the 1998–1999 TUS, the decrease in AL is equivalent to about one-third of the urban–rural gap for adult men and one-half for women.

Although the estimated decline in AL for adult men and women appears plausible and quite large, it is instructive to consider what variables in the NSS-E drive these results. Descriptive statistics for all years using the NSS employment survey are reported in table S1.5 in the supplementary online appendix. Agriculture is one of the more physically active industries/occupations and declined considerably as a share of employment, from 60 percent to 43 percent as a share of main household industry; however, there was large and partly offsetting increase in construction work, from 3 percent to 12 percent, which is also very physically active. Within agriculture, the probability that individuals engaged in a specific manual-labor-intensive agricultural task in the previous week has fallen only slightly, e.g., 12 percent to 9 percent for harvesting activities, 2 percent to 1 percent for plowing. The share of women engaged mostly in domestic duties remains very high. Although some of these duties are very physically active, most have declined only slightly, with the largest effect coming from the decline in the probability of bringing water from outside the household premises from 11 percent to 5 percent, smaller effects coming from decreases in food processing and animal husbandry, and no change in the probability of collecting firewood or cooking/heating fuel (around 7 percent throughout the period). The predictive equations used adopt a more flexible specification, but the linear estimates from table 2 are also instructive. The 3.3 year increase in years of schooling for adults and the over 50 percent increase in real per capita expenditure imply only a modest decrease in AL over this period (about 3 percent) for demographically similar households, with a small offset from the decrease in average household size from 6.3 to 5.3 individuals.

The fact that TEE is falling for adult men, adult women, and children, yet rising for the population reflects the important role played by population-level demographic change. The share of children aged 14 and under in the population fell from about 40 percent in 1983 to 30 percent by 2012. This implies considerably higher TEE, not just because children are physically smaller and have lower REE, but because children are also much less active than adults according to the TUS estimates, particularly in rural areas. In 1983 child TEE was about 60 percent of adult TEE, implying that the demographic shift over the 1983–2012 period, holding constant average adult and average child TEE, would generate a 4.7 percent *increase* in population TEE.

Comparison of TEE with Caloric Intake, Measurement Error, and Estimates of Disease Effects

Table 4 combines several data sources to provide an overall assessment of trends and levels for nutrition for India between 1983 and 2012. Columns 1 and 2 provide an illustration of the basic puzzle raised by Deaton and Drèze (2009). Column 1 shows that real per capita expenditure (deflated to 1993–1994 rupees) has increased, particularly in the most recent years since 2005. Column 2 reports official estimates of caloric intake from the National Sample Survey Organization (NSSO 2013) that are almost identical

Table 4. Comparison of Daily Total Energy Expenditure, Caloric Intake, Caloric Burden of Disease, and Caloric Surplus Implied by Weight Gain

	Consumption					TEE		Disease			Surplus
	Real mpce (1)	NSS calories (2)	NSS cal. 7-day (3)	Share 7-day (4)	Authors' cal. (5)	Pop TEE (6)	Adult TEE (7)	High (8)	Mid (=IMR) (9)	Low (10)	NFHS (11)
1983	302	2,190	2,307[*]	0.37	2,186	2,136	2,557	184	106	45	
1988	305	2,202	2,337[*]	0.42	2,180	2,134	2,553	165	95	40	
1994	321	2,133	2,269[*]	0.43	2,139	2,158	2,553	141	81	35	
2000	350	2,151	2,290[*]	0.44	2,169	2,155	2,531	118	68	29	10.5–12.7
2005	355	2,040	2,184[*]	0.48	2,083	2,172	2,524	99	57	24	10.5–12.7
2010	386	2,000	2,140	0.48	2,017	2,159	2,471	80	46	20	10.5–12.7
2012	479	2,087	2,225	0.49	2,044	2,153	2,446	73	42	18	10.5–12.7
Δ 1983–2012		−102	−82		−142	17	−111	−111	−64	−27	
Δ 1983–2005		−150	−123		−102	36	−34	−86	−49	−21	
Δ 2005–2012		47	41		−40	−19	−78	−26	−15	−6	

Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey, the National Family Health Survey (NFHS) rounds 2, 3, and 4, and the National Sample Survey (NSS) rounds 38, 43, 50, 55, 61, 66, and 68, with independent estimates by other authors cited below.

Note: Column 1 is the authors' calculation of real mean per capita expenditure (mpce) using NSS Schedule 1. Column 2 is the official estimate of caloric intake from NSSO (2013) using the 30-day recall period (with Deaton and Drèze (2009) for 1988 as this is missing in the report). Column 3 is the official estimate using the new schedule type 2, which uses a 7-day recall for all food except cereals, dairy, and pulses. [*] indicates our imputation, based on the share of expenditures on the 7-day recall items (column 4) and the difference in caloric intake between the 30-day and 7-day schedule. Column 5 is the authors' independent estimate of caloric intake (see appendix). Columns 6 and 7 are the authors' population and adult total energy expenditure (TEE) estimates. Columns 8 through 10 are based on the reported coefficients for the calorie–disease slope in Duh and Spears (2017), where disease is proxied by infant mortality. Column 9 reports infant mortality rate (IMR) for India (per 1,000 live births) from the World Development Indicators and the mid-level estimate based on a slope coefficient of 1. Columns 8 and 10 multiply IMR by 1.74 and 0.426, the high- and low-end estimates reported in Duh and Spears (2017, table 8). Column 11 "Surplus" is the net caloric surplus consistent with average weight gain using the NFHS data (see text and table S1.8 in the supplementary online appendix).

to the numbers reported in Deaton and Drèze (2009) for the 1983–2005 period but incorporate the latest available data (NSS Rounds 66 and 68 conducted in 2009–2010 and 2011–2012). The official numbers show that caloric intake declined further from 2005 to 2010, but then increased considerably from 2010 to 2012, which erased almost half of the decline between 1983 and 2005 measured in Deaton and Drèze (2009).

Columns 3 and 4 of table 4 provide some insight into measurement error related to recall bias. It is well known that longer recall periods can lead to downward-biased estimates of consumption, and the 51st through 54th NSS rounds (1994–1999) randomly allocated a 7-day as well as traditional 30-day recall period for food across households. The results confirmed that consumption estimates are higher for the 7-day recall period, but also that the difference was much larger for food categories like fruits and vegetables, eggs, fish and meat, and beverages and processed foods (over 40 percent) compared to under 15 percent for categories like milk and cereals (National Sample Survey Organization 2000). These findings led the NSS to use two different recall periods (canvassed for different households) for the food categories with the highest discrepancy between 7-day and 30-day recall periods in 2010 and 2012. For these categories, the magnitude of 7-day/30-day bias was similar to the earlier 1994–1999 period at around 44 percent for caloric intake (NSSO 2013, tables 5A and 5B).[6]

These facts about recall bias in the NSS have two implications for the analysis. First, assuming that the 7-day recall period is more accurate, the overall level of caloric intake in the NSS data using a 30-day recall period is substantially biased downward. The difference in levels of caloric intake between the two recall periods in 2010–2012 is as large as the entire measured decline between 1983 and 2005 or between 1983 and 2012 using the consistent 30-day recall period, and this underestimates the overall bias since categories like cereals and milk (which in 2010 and 2012 are measured using a 30-day recall period for all households) also exhibit a downward bias for 30-day recall, albeit to a lesser degree (National Sample Survey Organization 2000). A higher estimate of caloric intake is more in line with the reported TEE estimates, particularly in recent years, when 30-day measures of intake are well below the population TEE estimates. Second, the change in caloric intake over time using the 30-day recall period likely overstates the decline in caloric intake that would have been measured using 7-day recall, because the share of expenditures on the goods with the highest degree of bias rose from 36 percent to 50 percent between 1983 and 2010. Column 3 provides an illustrative estimate of what caloric intake in earlier rounds would have looked like under the assumption that the degree of bias for the 7-day recall categories in 2010 and 2012 remains constant over time. This assumption seems reasonable going back to 1994 in light of the results in National Sample Survey Organization (2000) but these estimates are intended to be illustrative and need to be treated with caution, particularly for the 1980s where there is no direct measurement of 7-day versus 30-day recall bias. Column 3 reports the official results using the 7-day recall period for select foods in 2010 and 2012 (from NSSO 2013) and imputations for earlier years that adjust caloric intake upwards but by a smaller percentage for earlier years (reflecting the change in the expenditure share of these categories reported in column 4). The result of this exercise is that the decline in caloric intake is about 20 percent smaller over the 1983–2005 period considered in Deaton and Drèze (2009) or the entire 1983–2012 period.

Beyond the potential effects of recall periods on measurement error, numerous imputations are required to estimate caloric intake from a given NSS survey and these imputations have become more important over time. Alternative estimates of caloric intake using NSS data, reported in column 5, provide a sense of the magnitudes of this source of measurement error. The details of the procedure are discussed in

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[6] Note also that the use of 30-day and 7-day recall periods for the *same* households in the 55th NSS round (1999–2000) is likely to account for some of the unusual pattern in table 4 whereby caloric intake rose from 1994 to 2000 and fell from 2000 to 2005. The discrepancy between 30-day and 7-day recall quantities appears smaller when the recall periods are implemented simultaneously for the same households, but the level of 30-day recall is likely to be higher than for households that are not subjected to an additional 7-day recall period (see Deaton and Kozel (2005) for a discussion).

Appendix C, but the main departure from the standard NSS practice is imputation of calories for most expenditures in the beverage and processed food categories (which includes purchased "meals"). These expenditures rise from about 5 percent to 9 percent of average household food expenditure, and as they lack quantities or report units like "number of cooked meals" or "number of cold beverages: bottled/canned," untested assumptions about how to impute their caloric value have become more important. The procedure used here yields very similar levels of estimated intake for 1983 through 1994, but a substantially smaller decline between 1994 and 2005, such that the total decline between 1983 and 2005 is only 66 percent as large as estimated by NSSO (2013) or Deaton and Drèze (2009). The estimates begin to diverge even more after 2005—while there is a similar pattern of decline from 2005 to 2010 and recovery from 2010 to 2012, overall the decline between 2005 and 2012 is about 40 calories per day as opposed to an increase of 47 per day according to official estimates. The alternative assumptions are not necessarily better than the official procedure, as there is no "ground truth" against which to assess either measure. Rather, the point is that measurement assumptions can have a large effect even using the *same data*, particularly in recent years when the importance of cereals and other unprocessed agricultural staples has fallen. These imputation assumptions have the potential to generate bias of a similar magnitude to the recall errors that potentially bias down both the level and decline in caloric intake.[7]

Returning to the other side of the calorie equation, columns 6 and 7 again report estimates of population TEE and average TEE for adults. Relative to the official estimates using the 30-day recall period, the estimated population TEE is almost perfectly negatively correlated over different time periods—it is rising from 1983 to 1994, stable over 1994 to 2000 when intake appears to increase, peaks in 2005 when caloric intake is near its minimum, and then declines from 2005 to 2012 when caloric intake rises. Furthermore, by 1994, intake using 30-day recall is below TEE and by 2005 it is *much* lower. The levels of TEE estimated in later periods are more consistent with the estimated caloric intake using the 7-day recall period. The alternative estimates of caloric intake in column 3 (using the 30-day recall) are also lower than TEE in the later period, but display a similar decline between 2005 and 2012, such that TEE could "explain" about half of the decline in caloric-intake estimates during this period. In column 7, average TEE for adults is reported to once again underscore that, were it not for demographic change, changes in estimated TEE for adults would be enough to "explain" a decrease in caloric intake of 34 calories per day between 1983 and 2005 (about 20 percent of the 150 calorie decline in the official estimates) or 111 calories per day between 1983 and 2012 (over 100 percent of the 102 calorie decline in the official estimates).

Further evidence that changes in TEE may have contributed to lower caloric intake between 2005 and 2012 but are unlikely to have done so for the 1983–2005 period comes from an analysis of state-level changes. Figure 2 plots the change in state caloric intake against the change in state TEE for the 1983–2005 period and the 2005–2012 period. In the earlier period, although there are some states that appear to line up along the 45 degree line, most lie well below, indicating that measured caloric intake relative to TEE declined. The association is also very weak and not statistically significant. In the later period, the relationship is considerably stronger, with most states lining up along the 45 degree line and a statistically significant slope of 0.666 (with associated R^2 of 0.08). Using the full state panel, TEE estimates are significantly correlated with changes in caloric intake within states over time.[8]

Given that the finding that population TEE rose during the 1983–2005 period of falling caloric intake considered by Deaton and Drèze (2009), it is worth considering the best estimates of the potential effect of the disease environment on caloric intake from Duh and Spears (2017). They use a district panel

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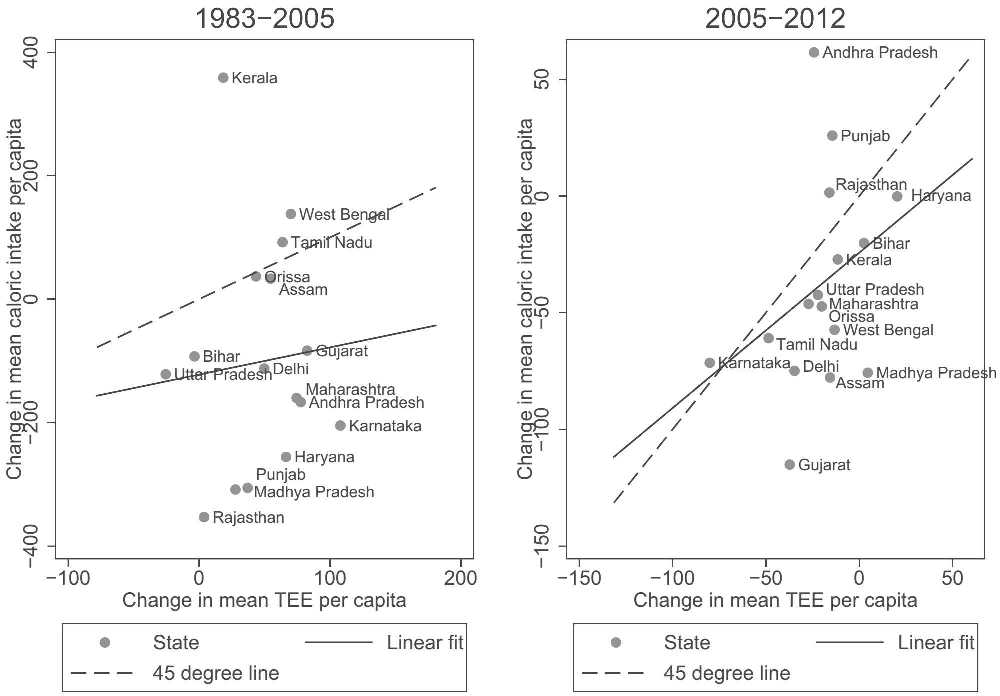
[7] Note that per capita caloric-intake levels under any methodology are somewhat sensitive to outliers, and the analysis here follows the standard practice of censoring the distribution around the 1st and 99th percentile cutoffs (corresponding to 960 and 4,400 calories a day per capita). However, the trend in population averages over time is not very sensitive to outliers and generally tracks the population median.

[8] See table S1.6 in the supplementary online appendix for these results.

Figure 2. Changes in Per Capita Caloric Intake and Total Energy Expenditure by State, 1983–2012



Source: Authors' analysis based on data from the 1998–1999 India Time-Use Survey, the National Family Health Survey rounds 2, 3, and 4, and the National Sample Survey (NSS) rounds 38, 43, 50, 55, 61, 66, and 68.

Note: State-level average total energy expenditure (TEE) is imputed using NSS Schedule 10 as described in the text and caloric intake per capita is the authors' estimate using NSS Schedule 1. The scatter plot excludes states with population below 10 million for readability.

to show that within-district decreases in infant mortality between 1988 and 2005 are associated with within-district decreases in NSS caloric intake, with a slope coefficient of about 1.7. They find smaller but still highly significant cross-sectional associations between village/block infant mortality and caloric intake using a different survey, with slope coefficients ranging from 0.426 (when including household and demographic controls) to 1. They also report results based on open defecation and latrine ownership, but infant mortality has data available for the entire period and plausibly captures changes in the disease environment related to diarrhea, parasites, and intestinal distress that could impede nutrient absorption and potentially raise TEE. Column 9 of table 4 reports the level of infant mortality (per 1,000 live births), which declined from 106 to 42 over this period. This can be interpreted as a mid-level estimate of the total caloric burden of disease using the slope coefficient of 1 and linear specification reported in Duh and Spears (2017), and low- (column 8) and high-end (column 10) estimates are also reported based on coefficients reported in their paper. Quantitatively, the decline in infant mortality mirrors the fall in caloric intake between 1983 and 2005, although the timing of the decline does not fit as well with the between-round variation (e.g., the huge drop in caloric intake between 2000 and 2005). If these estimates capture the true caloric burden of disease, they also imply that caloric-intake measures (official, or the independent estimates presented here) using the 30-day recall period must almost surely be too low, particularly in recent years, but the estimated caloric burden of disease is of the correct magnitude to reconcile the TEE estimates with the official 7-day recall period estimates.

A final piece of evidence on net nutrition comes from anthropometric data. Deaton and Drèze (2009) recognize that there has been some increase in average height in India during the 1983–2005 period, a trend that has continued since, although the level of height and the rate of increase remain low compared to other countries with similar GDP per capita and economic growth trajectories. Smith (2015) cites additional evidence of improving nutritional outcomes for children. A rise in average body mass for individuals of a given age and sex is one of the factors contributing to the increase in population REE estimated in this paper.[9] Although changes in height undoubtedly reflect nutrition, the quantitative relationship between net caloric surplus (intake minus TEE and any caloric cost of disease) and height is not well known. Changes in population height may be more reflective of micronutrients, macronutrients composition, and the timing of life-cycle nutrition from conception to adolescence rather than changes in the average caloric surplus of the population. However, the NFHS allows for measurement of weight gain over time, which does have a well-known quantitative relationship with caloric surplus. While a single cross-section allows comparisons of weight only across cohorts, the availability of multiple NFHS rounds allows for estimation of average weight gain with age for adults *within cohort*. In table S1.8 in the supplementary online appendix, the average weight gain is estimated controlling for cohort (birth-year) fixed effects across survey rounds, with data availability allowing for measurement of average weight gain between 2005 and 2015 for men and women, and between 1998 and 2005 for ever-married women. Estimates controlling for height are also reported, which may capture some non-random attrition within a cohort related to nutritional status. The data imply an average weight gain of between 0.5 kg and 0.6 kg per year within cohort, with a slightly higher rate between 2005 and 2015 than between 1998 and 2005 for ever-married women. A weight gain of 1 kg is associated with a caloric surplus of 7,700 for adults (St. Jeor and Stumbo 1999), so the reported level of weight gain translates into between 10.5 ($= 0.5 * 7{,}700/365$) and 12.7 ($= 0.6 * 7{,}700/365$) surplus calories per day above TEE and the caloric cost of disease. This suggests that, on average, the Indian (adult) population has been in caloric surplus since at least 1998 and even more between 2005 and 2015, even as official NSS caloric-intake estimates using 30-day recall plummeted during the 2000s to reach levels well below the TEE estimates. Given that the analysis above suggests a limited scope for such a large decrease in population TEE, and that most of the improvement in the disease environment occurred before this period, the overall evidence is consistent with the view espoused in Smith (2015) that the steep decline in official caloric-intake estimates beginning around 2000 is likely the result of substantial measurement error.

4. Conclusion

In this paper, population-level TEEs for India over the 1983–2012 period are quantified using a combination of time-use data, anthropometric data, and the NSS Schedule 10 employment survey. The main finding is that population TEE was fairly flat over this period, rising slightly until 2005 and then declining slightly only in the 2005–2012 period. This finding is driven by two main features of the data. First, household characteristics that tend to predict lower activity levels, such as education, expenditures, and industry/occupation, also tend to be associated with greater height and weight that imply offsetting increases in metabolic requirements. Second, even though the TEE estimates for adults in India fell by over 100 calories per day between 1983 and 2012, more than enough to account for the measured decline in caloric intake and equivalent to between a third and a half of the average rural–urban gap around 1998, there was substantial demographic change in the population that more than offset this effect. The share of children under age 15 fell from 40 percent to 30 percent during this period, and the analysis shows that they have both lower metabolic requirements and substantially lower activity levels, particularly in rural areas. Because the average TEE of adults is much higher than children, population-level demographic

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[9] In table S1.7 in the supplementary online appendix, even larger increases in REE for adults and children and hence smaller decreases (or even small increases) in TEE over the 1983–2012 period are found when including a linear time trend in the REE prediction equation. This may be reasonable in the later period but is likely to be a heroic assumption when extrapolating back 22 years a linear trend observed between 2005 and 2015.

change of the magnitude that occurred in India during this period exerts very powerful upward pressure on population TEE, enough to offset reasonably large reductions in TEE for a given age/sex. Thus, although variation in TEE can help account for the caloric-intake household-size relationship explored in Deaton and Paxson (1998), and can explain some of the national and cross-state patterns of caloric intake in the 2005–2012 period, it appears unlikely that a large reduction in TEE could "explain" the decline in caloric intake measured in the NSS. To the extent that there was a real (as opposed to measured) decline in population caloric intake during the 1983–2005 period, an improving disease environment (as shown by Duh and Spears 2017) is a more likely explanation. The estimates of TEE reported here are also consistent with a large degree of measurement error in NSS caloric intake, which recent data suggest is large enough to plausibly explain much of the apparent decline.

Although TEE is not usually considered by economists, the analysis suggests that there are interesting insights from quantifying it. Better measures of TEE could be used for the formulation and revision of poverty lines and equivalence scales, although given the difficulty of accurately measuring caloric intake or TEE it seems clear that anthropometric outcomes (e.g., stunting, wasting, body mass index, and weight gain over time) are more reliable for the evaluation of adequate nutritional status. Estimates of TEE could also be useful inputs into quantitative models of structural and demographic change since "subsistence" food requirements may vary with mechanization and household composition. In addition, quantifying TEE is a useful contribution to debates about estimated caloric intake and nutritional outcomes—given the scope for measurement error, measuring both calories in, calories out, and net caloric surplus can shed light on biases in measurement. Time-use and anthropometric surveys are available for many developing countries, and the potential availability of multiple waves of time-use data in developing countries could be particularly useful for this type of exercise, as it may allow for better quantification of changes in physical activity levels related to travel and the intensive (per hour) and extensive (number of hours) physical margin of domestic and market work that are harder to quantify with the methodology and data adopted here. Another promising alternative to costly household surveys is the use of technology for the purpose of capturing TEE. Most modern smartphones can track physical activity levels reasonably well and simple devices that monitor heart rates offer the potential to estimate variation in activity levels for larger samples, greatly increasing the scope for estimating activity levels for populations outside the laboratory relative to the prohibitively expensive chemical methods that prevail in the nutrition literature.

Appendix A. Estimation of REE

The best anthropometric predictor of REE is fat-free mass, but as this is rarely measured in the field, prediction equations have been developed based on regressing laboratory measured REE on more commonly observed variables (St. Jeor and Stumbo 1999). A standard approach, adopted by FAO/WHO/UNU Expert Consultation (2001) and Indian Council of Medical Research (2009), is to use prediction equations that regress REE on gender, age, weight, and in some cases height. Estimating separate equations by age and sex, and incorporating height, helps account for systematic average differences in fat-free mass, e.g., women, older, and shorter individuals tend to have lower fat-free mass for a given weight. Equations provided in Henry (2005) use height and weight and are estimated separately for several age/sex groups. Results are not very sensitive to the use of alternative prediction equations. In supplementary online appendix table S1.1, panel A, alternative REE estimates are generated using the prediction equations used by Indian Council of Medical Research (2009). Similar results can be obtained using the prediction equations from St. Jeor and Stumbo (1999). There have been laboratory measurements of REE in India but none for a large or representative sample of individuals and none generating specific predictive equations. Ferro-Luzzi et al. (1997) attempt a validation of the Food and Agriculture Organization (FAO) equations on Indian data and find a reasonable fit.

The method used here for imputing REE to individuals in other data sets is to regress the REE predicted by the Henry (2005) equations using the age, sex, height, and weight from the NFHS on a set of common variables available in the NSS Schedule 10 employment survey. Because age and sex are always observed, this procedure generates additional variation in TEE conditional on age and sex that captures average differences in height and weight associated with socioeconomic status, maternal and childhood nutrition. Table S1.4 in the supplementary online appendix reports the variables and coefficients for these regressions, which include individual and household age, education, demographics, school attendance, land holdings, and two-digit primary occupation code (using NCO1968 classification and available concordances for the later NFHS rounds). Separate equations are estimated by sector and sex, pooling the available years of data (which include 1998 for women and 2015 for both men and women) and including year fixed effects (the omitted category is 2005). In principle one could also use separate predictive equations for height and weight, and then apply the Henry (2005) equation, but results are similar either way.

Note that these equations can only be estimated for the adult age ranges in the NFHS eligible for height and weight measurement (15–49 for women and 15–54 for men). For individuals outside this range, the following procedure is adopted:

1. Assume that their age is equal to 15 or 49 (54 for men) and use the predictive equation for REE.
2. Scale this REE by the ratio of average REE for that individual's age and sex relative to the average REE for their "assumed age" used in the predictive equation.

REE is scaled using the age- and gender-specific mean height and weight reported by the National Nutritional Monitoring Bureau for rural areas of 16 Indian states between 2000 and 2002 (reported in Indian Council of Medical Research 2009), together with the Henry (2005) equations. Note that Indian Council of Medical Research (2009) uses the 95th percentile of this same distribution to generate their recommended daily caloric intake, highlighting an important difference between prescriptive estimates of recommended daily caloric intake and the descriptive estimates of population TEE reported here.

The estimates reported in the text make two additional adjustments. First, because children under 18 are still growing, calories consistent with "normal" growth (the pattern of observed weight gain) are added. This adjustment uses the 2 kilocalories per gram of tissue synthesis suggested in FAO/WHO/UNU Expert Consultation (2001) combined with the average annual weight gain for each age and gender in the National Nutrition Monitoring Bureau data. Adjustments for the additional energy required by pregnant or nursing mothers are difficult due to lack of data, but energy requirements of infants themselves can be included. REE for infants (children under age 1) is set such that male babies have TEE of 650 calories and female babies have TEE of 600 calories, consistent with the Indian Council of Medical Research (2009) report. Second, values outside the 1 percent of the tails of the distribution are replaced with the percentile cutoff values prior to estimation.

Appendix B. Estimation of ALs

Table S1.2 in the supplementary online appendix lists the time-use survey activity codes and headings, the average share of time spent on the activity by rural and urban individuals, and the matched activity factors from FAO/WHO/UNU Expert Consultation (2001). Estimates are not very sensitive to using alternative sources of activity factors, such as those developed for richer countries that tend to contain more detailed classifications of sports and exercise activities. Table S1.2 in the supplementary online appendix includes the matched activities and activity factors from Ainsworth et al. (2000) (used by Cutler, Glaeser, and Shapiro 2003) for comparison, and supplementary online appendix table S1.2, panel C shows that the difference in activity levels using the measure used in the text and this alternative set of activity factors is quite small.

The estimates reported in the text make two additional assumptions about activity factors to derive activity levels. First, since the time-use data report time spent on "related" or "other" activities within certain headings, one must assign an activity factor in these cases. The activity factor used in this case is equal to the average for the activities matched under the same heading. Second, since mode of travel is unobserved, the estimates use a single activity factor equal to 3 for all travel. This seems reasonable given that car ownership is very low in India and many other forms of transport (including bicycles, motorcycles, animal-carts, and public transit) are equally and sometimes more energy intensive than walking. For example, FAO/WHO/UNU Expert Consultation (2001) reports activity factors for "sitting on a bus/train" (1.2), "driving a car/truck" (2.0), "walking around/strolling" (2.1), and more intense activities like "carrying a 20–30 kg load on head" (3.5), "walking quickly" (3.8), and "cycling" (5.6). An activity factor for travel of 3 lies between these extremes, and it is in the same range as "walking slowly" and "driving a motorcycle." Based on NSS data, the car ownership rate in rural areas as late as 2005 was only 1 percent, and in urban areas was only 3 percent. Motorcycle and bicycle ownership rates are higher in 2005 (8 percent and 48 percent respectively in rural areas, 25 percent and 44 percent in urban areas). The approach used here still allows better-off households (proxied by per capita expenditure) to economize on travel time by using faster modes of transport, which leads to lower activity levels since travel is fairly energy intensive compared to most other activities, but does not allow for potentially higher or lower activity factors associated with different modes of transport for a given amount of travel time measured in the TUS.

To impute activity levels to individuals in the NSS-E, individual activity levels in the TUS are regressed on a set of common variables to generate predictive equations. Separate equations are used for each combination of rural/urban, male/female, under 15 and over. Table S1.3 in the supplementary online appendix presents the set of variables and regression coefficients for these regressions, which include detailed age and household demographics, education levels, land, per capita expenditure, household and individual two-digit NIC (1987 National Industry Classification) and NCO (1968 National Classification of Occupations), and work status variables (e.g., self-employed, casual worker, salaried worker, student, domestic duties). Dummy variables are also constructed for the TUS to match the detailed agricultural task variables (based on the previous week) and domestic chores (for women with primary status as domestic), based on whether households report any time spent during the last week on activities like weeding, harvesting, caring for animals, collecting firewood or water, food collection and preparation. As with REE, values outside the 1 percent of the tails of the distribution are replaced with the cutoff values prior to estimation. For individuals younger than 6, activity levels are set equal to the sample mean for 6-year-olds, which is 1.46.

Appendix C. Estimation of Caloric Intake

For alternative, independent caloric-intake estimates reported here, the NSS consumption survey (Schedule 1) is used for the same years as the NSS-E. For 2010 and 2012 the main results use a comparable 30-day recall period. Household respondents are asked to recall the total quantity and expenditure for each food item from a detailed list over the previous 30 days. The standard methodology of directly converting quantities of each food into calories using the calories per unit weight for each item reported in Gopalan, Sastri, and Balasubramanian (2004) is used, with additional supplemental data from the MedIndia website.[10] This covers 90.8 percent to 95.4 percent of average household food expenditure between 1983 and 2012.

For goods that have missing units or that are classified as "other" within a major category heading (e.g., fruits, vegetables, meat, dairy), calories proportional to the average calorie per rupee calculated within

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[10] See http://www.medindia.net/calories-in-indian-food/index.asp.

that category and NSS region are assigned. This increases the share of food expenditures covered by an additional 0.5 percent. The rest of food expenditures fall under the processed food and beverages categories, where the lack of units and/or vague classification make the use of a caloric conversion difficult if not impossible, e.g., the count of cooked meals or "cold beverages bottled/canned" or unitless expenditures on "prepared sweets" or "salted refreshments." Calories from reported tea, coffee, and alcohol consumption are straightforward to incorporate because their units are reported. For the other goods, the reported estimates assume that calories per rupee are equal to 50 percent of the calories per rupee that can be directly converted across all goods. Ingredient costs appear to make up 40 percent of the sale price at large Indian restaurants (Federation of Hotel and Restaurant Associations of India 2004) while the value for richer countries is typically in the 20–35 percent range. A value of 50 percent puts the calories/rupee of processed foods, beverages, and cooked meals roughly equal to the dairy category, while a value of 66 percent puts it equal to pulses or pure sugar.

The other adjustment made is similar to the official NSS estimates, which incorporate survey information on the number of meals consumed by household members at home and away on payment (which are drawn from the calories measured in the survey), the number of free meals consumed away from home through employers, schools, and other households (which are not included in the survey quantities), and meals given to non-household members (which are drawn from the survey quantities but do not contribute to household caloric intake). The simple adjustment factor is based on the formula *adjustment factor = (meals at home + meals away from home free)/(meals at home + meals to others)*. This assumes that households that consume more calories per meal at home both give and receive free meals that are proportionately higher in calories, and that free meals given and received enter symmetrically. The reported estimates censor the estimated distribution at 960 (equivalent to the 1 percent cutoff in 1983) and 4,400 (the 99 percent cutoff in 2012), which lowers the estimated level of intake for some years due to the presence of large right-tail outliers but has a minimal effect on the trends.

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