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Macronutrients and obesity: Revisiting the calories in, calories out framework

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ABSTRACT

Recent clinical research has studied weight responses to varying diet composition, but the contribution of changes in macronutrient intake and physical activity to rising population weight remains controversial. Research on the economics of obesity typically assumes a "calories in, calories out" framework, but a weight production model separating caloric intake into carbohydrates, fat, and protein, has not been explored in an economic framework. To estimate the contributions of changes in macronutrient intake and physical activity to changes in population weight, we conducted dynamic time series and structural VAR analyses of U.S. data between 1974 and 2006 and a panel analysis of 164 countries between 2001 and 2010. Findings from all analyses suggest that increases in carbohydrates are most strongly and positively associated with increases in obesity prevalence even when controlling for changes in total caloric intake and occupation-related physical activity. Our structural VAR results suggest that, on the margin, a 1% increase in carbohydrates intake yields a 1.01 point increase in obesity prevalence over 5 years while an equal percent increase in fat intake decreases obesity prevalence by 0.24 points.
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1. Introduction & background

Research on the economics of obesity typically begins by adopting the "calories in, calories out" framework, in which an individual is assumed to gain weight if contemporaneous kilocalorie (hereafter, "calorie") consumption is greater than expenditure, and vice versa. This framework has been used extensively in the economics literature to guide empirical research into the determinants of obesity through the channels of food consumption and physical activity. For example, many studies model weight as a dynamic capital stock which changes according to a production function with food consumption and physical activity as inputs (e.g., Lakdawalla and Philipson, 2002) and then operationalize the production function as linear in caloric intake (e.g., Cutler et al., 2003).

Although there is a vast medical and epidemiological literature studying the relationship between diet composition and a variety of illnesses such as cardiovascular disease, high blood pressure, and diabetes (Appel et al., 2005; Hooper et al., 2001; Hu et al., 2001), researchers are still working to understand the myriad ways in which weight responds to varying diet composition (Seidell, 1998; Taubes, 2012; van Dam and Seidell, 2007). Because it is challenging to control dietary intake in an experimental setting over a long period of time, observational studies can meaningfully contribute to knowledge about the long-run, i.e., across several years, weight impacts of diet composition. Recent research has made substantial progress modeling weight accumulation under the first-order

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approximation that macronutrients are equivalent, but efforts thus far are most applicable to the short-run while long-run weight gain processes remain unknown (Hall et al., 2011).

Many important changes in the patterns of energy intake and expenditure have developed in the United States during the past 40–50 years. Between 1971 and 2000, total caloric intake increased while the proportion of caloric intake from carbohydrates increased and the proportion from dietary fat decreased (Wright et al., 2004). Underlying these changes, caloric intake from fat remained relatively stable while caloric intake from carbohydrates (and in total) increased (Austin et al., 2011). Notably, the use of caloric sweeteners increased substantially between 1962 and 2000 (Popkin and Nielsen, 2003). Although time-use surveys suggest that leisure-time physical activity remained relatively unchanged (Cutler et al., 2003), average occupation-related energy expenditure decreased by more than 100 calories between the early 1960s and mid-2000s (Church et al., 2011). These changes occurred while obesity prevalence almost doubled since the early 1960s (U.S. Department of Health and Human Services, 2012).

In contrast to assumptions underlying the static calories in, calories out framework typically implemented in models of utility maximization, different nutrients of equal caloric content could have varying contemporaneous and dynamic effects on weight. To understand this, first consider that one nutrient may be metabolized more efficiently than another in the sense that, for a given weight level and caloric expenditure, consumption of that nutrient results in greater net energy storage (e.g., in the form of fat) and less waste. In other words, some foods may be more "nutritious" than others with respect to energy conversion. A calorie is defined as the energy required to increase the temperature of one kilogram of water by one degree Celsius (Merril and Watt, 1973). However, the reported caloric content of a food is not necessarily equal to the energy absorbed by the body; for example, the energy contained in insoluble fiber is subtracted from total caloric content because it is understood to provide no physiological energy (U.S. Department of Agriculture, 2004).

That researchers continue to learn more about energy absorption and metabolism, however, suggests that subtracting fiber from carbohydrate caloric content may not be the only warranted adjustment in the context of equilibrium weight outcomes. For example, carbohydrates may vary in their digestibility or timing of digestion according to their glycemic index (Ludwig, 2002), and ongoing research suggests that some forms of carbohydrates, notably fructose, may play an important role in increased adiposity (Bremer et al., 2012; Stanhope et al., 2009).[1] Recent evidence accordingly supports the hypothesis that measured calorie content does not fully capture the risk of developing obesity. Qi et al. (2012) find that, even after controlling for self-reported total energy intake and expenditure, the intake of sugar-sweetened beverages strengthens the association between obesity risk and genetic predisposition to obesity.

In addition, a nutrient may have a different dynamic effect on weight gain from another if its consumption affects an individual's energy balance by inducing subsequent changes in the consumption of other foods or physical activity (Mozaffarian et al., 2011). In other words, some nutrients may be dynamic substitutes or complements. For example, one nutrient may be an incomplete caloric substitute for another by leaving an individual feeling less satiated when total calories are held constant, and evidence for a meaningful lack of substitutability among calorically equivalent foods continues to grow. Consistent with theoretical predictions about how the metabolism of different nutrients is related to satiety and insulin levels (Bremer et al., 2012; Ludwig, 2002), measured voluntary food intake is higher after eating a high glycemic index meal (Ludwig et al., 1999) and higher after ingesting liquid rather than solid sugar (DiMeglio and Mattes, 2000). Conversely, in a double-blind experiment in which children were given one daily sugar-containing or non-caloric beverage, weight gain was found to be less among the group randomly assigned the non-caloric beverage (De Ruyter et al., 2012).

Persistent changes in the composition of consumed nutrients due to relative price changes,[2] technological change, or dietary norms could therefore increase long run equilibrium weight in a dynamic setting such as that proposed by Cutler et al. (2003) through an increase in calorie consumption or changes in nutrient composition for a given calorie level. If consumers lack information about the relative contemporaneous effects of various nutrients for a given caloric content (a plausible hypothetical given that researchers are still working to understand the metabolic effects), and since weight gain is gradually cumulative and thus offers short-run feedback that is difficult to detect, a calorie counting consumer may inadvertently affect his or her weight accumulation by shifting consumption across nutrients while holding total calories constant. Alternatively, if some nutrients induce less satiety for a given calorie count, an individual who switches to less satiating nutrients may be more likely to experience the feeling of a loss of self-control since he or she will be "tempted" to eat a greater number of calories in a given time period. Indeed, this dynamic effect would provide incentives to food producers to minimize the satiety of a food product, for a given caloric content, in order to sell more food.[3]

Given the recently emerging evidence that suggests alternatives to the calories in, calories out framework, in

[1] Although these results are suggestive, there is substantial uncertainty about the role played by fructose because of the complexity and cost of truly informative experimental designs (Sievenpiper et al., 2012).

[2] There is evidence that changes in the average price per calorie in the U.S. have been insufficient to result in the observed increase in caloric intake and obesity prevalence, but relative prices between food categories have changed and may have contributed to substantial shifts in dietary macronutrient composition (Christian and Rashad, 2009).

[3] This implication is related, but not identical, to the idea that foods can be designed to specifically induce present-biased, or irrational, consumption behavior (Ruhm, 2012).

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