Time-saving Innovations and the Obesity Epidemic

by

David J. Malison

(Under the direction of Christina Marsh)

Abstract

Recent research shows that the adoption of time-saving technology in food preparation has contributed to the obesity epidemic. This paper develops a model explaining why firms adopt such innovations, providing insight into the growth of obesity over time and across countries. I find that wage increases, by raising the value of time, encourage firms to implement time-saving technology. I test this hypothesis by analyzing the effect of wages on the ratio of fast-food restaurants to grocery stores in the United States. I find that an increase in a county's average wage is correlated with an increase in a county's fast-food-to-grocery-store ratio, as predicted by the theoretical model. The results suggest that wage growth has contributed to the development of the obesity epidemic.

Index words: Obesity, technological innovation, time allocation, fast food

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Chapter 1

Introduction

Obesity is one of the most significant public health problems the United States confronts today. Flegal et al. (2010) report that approximately 35 percent of Americans over the age of 20 are obese (defined as having a body mass index (BMI) exceeding 30), while almost 70 percent are overweight (BMI ≥ 25). The rise in obesity is extremely costly: Finkelstein et al. (2009) show that Americans spent more than $140 billion in 2008 on obesity-related healthcare, accounting for almost 10 percent of US medical expenditures that year. If current trends continue, Wang et al. (2008) project that by 2030 over 85 percent of American adults will be overweight or obese and healthcare costs associated with obesity will account for 16-18 percent of all US healthcare expenditures ($860-956 billion).

Although the rise in obesity rates has placed a large burden on the United States' healthcare system, the problem is of a global scale. Berghöfer et al. (2008) find that the prevalence of obesity in many European countries is approaching that of the United States. Chen (2008) reports that obesity rates in China rose 97 percent from 1992 to 2002, and Matsushita et al. (2004) report a similar increase in the prevalence of childhood obesity in Japan. Prentice (2006) and Hossain et al. (2007) show obesity rates have tripled in underdeveloped countries around the world since 1970, with incidence rising most markedly in urban areas. Kelly et al.

(2008) estimate that more than 400 million individuals worldwide are obese, a number that is projected to increase to 1.12 billion by 2030.

Given the magnitude and continued growth of the epidemic, a better understanding of obesity is crucial to developing effective public health policy for the future. In this paper I show how wage growth is one of the root causes of the epidemic: higher wages encourage firms to provide food faster, but a tradeoff exists between the speed and quality of a meal. This theory helps explain why obesity has increased over time and is currently spreading to developing countries.

Several studies contribute to our understanding of the origins of obesity, and a comprehensive review of this literature is beyond the scope of this paper (Wang and Beydoun (2007) provide a recent review of obesity in the United States and Caballero (2007) offers a review of the epidemic around the world). I will only discuss two studies particularly relevant to my work. The first is Cutler et al. (2003), which analyzes how decreased time costs in the production of a meal, originating from innovations in food processing technology, have allowed people to consume more calories at a faster pace. Although these authors illustrate the importance of such technologies, they give no account as to why such innovations have been developed and implemented on a wide scale. I build on their work by showing how wage growth could encourage the technological changes behind the epidemic. The second study is a Chou et al. (2004) that notes how the market value of women's time influences the hours spent at home preparing food. Although these authors discuss the possibility of a relationship between wage growth and obesity, they do not formalize the argument in a theoretical model as I do here.

Chapter 2 of this paper presents the theoretical model in the simple case where wages are uniformly distributed on the unit interval. Chapter 3 extends this model to the case when wages are uniformly distributed on an arbitrary interval. This extension allows the model to predict how firms alter their behavior when wages grow. I find that wage growth increases the probability of a firm adopting a time-saving technology. In Chapter 4 I test this prediction using county-level data from the United States. I find that higher wages are correlated to a higher fast-food-to-grocery-store ratio, as predicted by my theoretical analysis. Chapter 5 concludes.

Chapter 2

The Theoretical Model

In this chapter, I present a model for the market of a good that is time-intensive to consume. In Section 2.1, I discuss the consumer's problem and develop demand curves from a utility function that incorporates the usage time of the good. In Section 2.2, I discuss the firm's problem and derive best-response functions that determine the firms' pricing behavior. I solve the model and derive the equilibrium price of the good in Section 2.3, and I discuss some implications of the model in Section 2.4.

2.1 Consumer's Problem

Consider a set of consumers that earn wages w, distributed uniformly on the unit interval. The consumers derive utility from consuming a unit of good x, which is produced by two firms ($i = 1, 2$) in the economy. Each firm charges p_i for the good, and it takes t_i units of time to consume good x from firm i. We will subsequently call t_i firm i's "time cost." The total price the consumer pays to use x is equal to the price firm i charges (p_i) plus what the consumer could have earned had he worked instead of buying the good (wt_i).

In general, the time cost a consumer pays when using a good can be divided into two components. One component depends on the market demand for the good and can be thought of as congestion. The time costs of loading a website or driving during rush hour depend heavily on congestion. The other component is intrinsic to consumption and must be paid regardless of the number of users. The time cost of watching a movie is a good example. I am primarily concerned with modeling the tradeoff between consuming a meal at home and buying a meal at a restaurant. Because the time costs associated with these activities depend little on aggregate demand, I ignore the congestion component to the time costs and assume that a constant time cost is paid whenever the good is purchased.

The consumers have identical preference functions defined by

$$U(x) = \begin{cases} v - wt_i - p_i, & x = 1 \\ 0, & \text{otherwise} \end{cases} \tag{2.1}$$

where v measures the enjoyment consumers receive from using x. I assume v is large enough that all consumers buy in equilibrium. Under this assumption, each consumer must only decide whether to purchase from firm 1 or firm 2. If the time costs are the same, the firms are identical to the consumers and the market is characterized by perfect competition (see Appendix). We are more interested in the case when the two firms have different time costs, which is true when, for example, the good is a meal and the two firms are interpreted as a grocery store and a fast food restaurant. Since no consumer would pay a higher price to incur a larger time cost, the firm with the higher time cost must charge a lower price to generate demand.

Figure 2.1 displays the utility received from purchase of the good for consumers earning different wages, assuming $t_1 > t_2$. The figure shows that consumers with low wages are better off purchasing from the firm with the high time cost (firm 1). The intuition behind this result is straight-forward: because their time is not very valuable, low-wage consumers

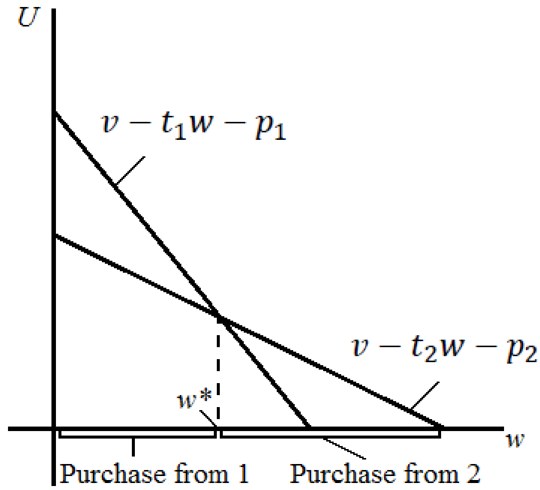

Figure 2.1: Consumer utility as a function of wage, assuming $t_1 > t_2$

choose to pay the higher price at firm 2 to save time. On the other hand, the time it takes to use the good is costly for consumers earning high wages; these consumers are willing to pay firm 2's higher price to save time. The wage of the marginal consumer indifferent between purchasing from either firm can be calculated as

$$
\begin{aligned}
v - w^* t_1 - p_1 &= v - w^* t_2 - p_2 \\
\Rightarrow \quad w^* &= \frac{p_2 - p_1}{t_1 - t_2}
\end{aligned}
\tag{2.2}
$$

It is clear from equation (2.2) that a marginal consumer only exists when $t_1 \neq t_2$. This condition follows from a point made earlier: when prices are the only dimension distinguishing the two firms (i.e. if $t_1 = t_2$), the firms engage in perfect competition and no marginal consumer exists. Graphically, this situation occurs when the two lines in Figure 2.1 are parallel.

Before proceeding to the firm's problem, it is worth discussing some possible generalizations. For example, since we are constructing a model to explain the obesity epidemic it might be useful to allow products to be differentiated by quality measures like healthiness or taste. Food quality and time of preparation tend to be substitutes rather than complements: although there are exceptions, meals that take a short time to prepare tend to be unhealthy (e.g. fast food, frozen dinners) or unappetizing (e.g. canned vegetables, pre-made salads). Furthermore, since health is a normal good, consumers with higher incomes might possess a greater preference for healthier foods. A general specification of a utility function allowing these considerations could be written as

$$U(x) = \begin{cases} v[w, H(t_i)] - wt_i - p_i, & x = 1 \\ 0, & \text{otherwise} \end{cases} \tag{2.3}$$

where H is a function that captures the relationship between the healthiness of the good and its time cost. Constraints could be imposed on the functions v and H to reflect beliefs about preferences and the tradeoffs between time cost and health.

Although this generalization will change the shape of the utility functions in Figure 2.1 it will not alter the model's main results, as long as v remains large enough that all consumers buy in equilibrium (i.e. $v[w, H(t_i)] - wt_i - p_i > 0$ for some i for all $w \in [0, 1]$). To see why, let U_1 and U_2 denote the utility the consumer receives from buying the good from firm 1 and firm 2, respectively. Then the consumer purchases from firm 1 if and only if $U_1 > U_2$. Rearranging this condition, we have

$$\begin{aligned} v[w, H(t)] - wt_1 - p_1 &> v[w, H(t)] - wt_2 - p_2 \\ \Leftrightarrow \quad w^* = \frac{p_2 - p_1}{t_1 - t_2} &> w \end{aligned} \tag{2.4}$$

Consumers with wages less than w^* purchase from firm 1 and consumers with wages greater than w^* purchase from firm 2, regardless of the functional form of v. In other words the demand curves that the firms face do not depend on the income and quality effects captured by v, and so it is reasonable to ignore these complications as we proceed.

2.2 Firm's Problem

Throughout this section continue to assume that $t_1 > t_2$ and that firms can alter their prices but cannot adjust time costs (in Section 3.2 I allow firms to pick their time costs). As discussed in the previous section, consumers earning wages less than w^* are better off purchasing from the firm with the high time cost (firm 1), while consumers earning wages greater than w^* are better off purchasing from the firm with the low time cost (firm 2). Since the consumers have wages uniformly distributed on the unit interval, the demand functions facing the two firms are

$$D_1(p_1, p_2) = \int_0^{w^*} 1dw = w^* = \frac{p_2 - p_1}{t_1 - t_2} \tag{2.5}$$

$$D_2(p_1, p_2) = \int_{w^*}^{1} 1dw = 1 - w^* = 1 - \frac{p_2 - p_1}{t_1 - t_2} \tag{2.6}$$

where we have substituted for w^* using equation (2.2). The firms produce the good at a constant marginal cost c, and each firm takes the price of the other firm as given. The profit functions for the two firms are then

$$\pi_1(p_1, p_2) = (p_1 - c)\frac{p_2 - p_1}{t_1 - t_2} \tag{2.7}$$

$$\pi_2(p_1, p_2) = (p_2 - c)\left(1 - \frac{p_2 - p_1}{t_1 - t_2}\right) \tag{2.8}$$

The first-order conditions for profit maximization are

$$\frac{2p_1^* - p_2 - c}{t_1 - t_2} = 0 \tag{2.9}$$

$$\frac{2p_2^* - p_1 - c}{t_1 - t_2} - 1 = 0 \tag{2.10}$$

where p_1^* and p_2^* denote equilibrium prices.

It may appear unrealistic to assume that only two firms compete in the market. However, recall that a primary purpose of the model is to yield insight into the choice to cook at home or dine out. With this interpretation in mind, it is reasonable to construct the model so that the consumer chooses between only two firms. The model is flexible enough to allow for more firms, but this generalization introduces algebraic complications without adding much insight. For n firms with n different time costs, we could use the utility function in equation (2.1) to solve for $n-1$ marginal consumers. We could then derive the demand curves implied by these marginal consumers and proceed exactly as in the two firm case, but with n first order conditions. To keep things simple and easy to interpret, I will continue to assume there are only two firms throughout the duration of this paper.

2.3 Equilibrium

The first-order conditions contained in equations (2.9) and (2.10) define the "best-response" functions of each firm (i.e. the optimal price set by each firm as a function of the price set by the other firm). These functions are graphed in Figure 2.2. At an equilibrium both equations must hold; otherwise the firms would have an incentive to adjust their prices. Solving for p_1^* from equation (2.9) and substituting this into equation (2.10) allows us to solve for p_2^* in terms of the parameters of the model. This value for p_2^* can then be substituted back into equation (2.9) to give the equilibrium prices at both firms:

$$p_1^* = \frac{1}{3}(t_1 - t_2) + c \qquad\qquad p_2^* = \frac{2}{3}(t_1 - t_2) + c \tag{2.11}$$

These price equations illustrate how the firms are able to charge a price above marginal cost when their products are differentiated in terms of time costs. They also show that the firm

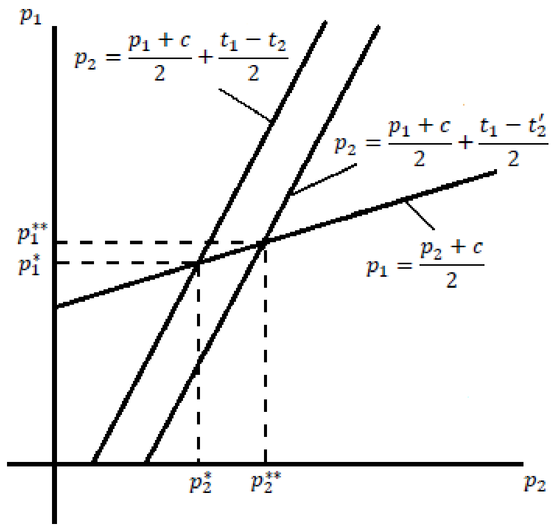

Figure 2.2: Best response functions

with the higher time cost (firm 1) must charge a lower mark-up to attract customers, as was mentioned previously. Substitution of these prices into equation (2.2) reveal that the marginal consumer has a wage equal to 1/3, which lies on the unit interval as we would expect. We can also substitute equation (2.11) into equations (2.7) and (2.8) to determine equilibrium profits:

$$\pi_1^* = \frac{1}{9} \cdot (t_1 - t_2) \qquad\qquad \pi_2^* = \frac{4}{9} \cdot (t_1 - t_2) \tag{2.12}$$

The firm with the higher time cost (firm 1) makes less profit, which is intuitive since the firm with the higher time cost charges a lower price to attract consumers.

2.4 Discussion and Implications

The model developed in the previous sections describes how two firms compete when a time cost is associated with their products. The firm with the higher time cost must lower prices to generate demand, and thus makes a smaller profit. Note that equations (2.11) and (2.12) indicate profits and prices at both firms increase as the time cost differential $t_1 - t_2$ grows. This result stems from the fact that the prices set by the two firms are strategic complements. If firm 2's time cost falls, it can afford to raise prices without sacrificing much market share (see Figure 2.2, which illustrates the change in firm 2's best response function when t_2 falls). But higher prices at firm 2 permit firm 1 to raise its prices as well, causing profits for both firms to grow.

How do the time costs affect consumer welfare? Would consumers be better off if the time costs were lower? To answer these questions, use the consumer's utility function (equation (2.1)) to calculate the total utility derived from consumption in this market:

$$\begin{aligned}
U_{total} &= \int_0^{w^*} (v - wt_1 - p_1^*)dw + \int_{w^*}^1 (v - wt_2 - p_2^*)dw \\
&= [(v - p_1^*)w + \frac{t_1 w^2}{2}]\Big|_0^{w^*} + [(v - p_2^*)w + \frac{t_2 w^2}{2}]\Big|_{w^*}^1 \\
&= \left[(v - p_1^*) + \frac{t_1(p_2^* - p_1^*)}{2(t_1 - t_2)}\right]\left(\frac{p_2^* - p_1^*}{t_1 - t_2}\right) + v - p_2^* + \frac{t_2}{2} \\
&\quad - \left[(v - p_2^*) + \frac{t_2(p_2^* - p_1^*)}{2(t_1 - t_2)}\right]\left(\frac{p_2^* - p_1^*}{t_1 - t_2}\right) \qquad (2.13) \\
&= \left[(v - \frac{1}{3}(t_1 - t_2)) + \frac{t_1}{6}\right] \cdot \frac{1}{3} + v - p_2^* + \frac{t_2}{2} \\
&\quad - \left[(v - \frac{2}{3}(t_1 - t_2)) + \frac{t_2}{6}\right] \cdot \frac{1}{3} \qquad (2.14) \\
&= v - c - \frac{t_1}{2} + t_2
\end{aligned}$$

where we have substituted in for w^*, p_1^*, and p_2^* using the results derived above. We can see from this equation that consumers are actually made slightly worse off when the time cost at firm 2 becomes lower. This is because a smaller t_2 increases the time cost differential $t_1 - t_2$, allowing both firms to raise prices; the utility lost from higher prices more than offsets the utility gained from the lower time cost. On the other hand, consumers are made better off when the time cost at firm 1 declines. This change not only reduces the time cost paid by consumers earning less than w^*, but also decreases the time cost differential. The smaller time cost differential reduces prices at both firms, benefiting consumers.

Returning to our interpretation of the firms as representing the cooking-at-home and dining-out industries, this result suggests that decreases in the time it takes to eat at home, for example the introduction of microwave ovens and frozen foods, promote gains in consumer welfare. Faster cooking times at home not only benefit consumers in terms of a lower time cost, but also pressure restaurants to lower their prices. If these lower time cost foods are less healthy, however, there would be an offsetting effect on welfare not accounted for in this model. The previous section also showed that the equilibrium wage was equal to 1/3, independent of the time costs at the two firms. This result indicates that changes in the time cost of food consumption only influences prices, and does not have an affect on the proportion of consumers dining out.

Chapter 3

Allowing for wage growth

The previous chapter established a baseline model in which wages were distributed on the unit interval. In this chapter, I explore how firms change their behavior when the wage distribution changes. In Section 3.1, I extend the model developed in Chapter 2 to a more general wage distribution. In Section 3.2 I allow firms to pick their time costs, and show how the location of the wage distribution affects how often firms choose the low time cost. I discuss some implications of the results in Section 3.3.

3.1 A more general wage distribution

Although the model developed in Chapter 2 constrained wages to lie on the unit interval, one can theoretically allow wages to be distributed by any continuous function $f(w)$ satisfying

$$\int_a^b f(w)dw = F(a) - F(b) = 1 \qquad \text{and} \qquad f(w) > 0, \text{ for all } w \in [a,b] \qquad (3.1)$$

where F is an antiderivative of f. Because the marginal consumer's wage w^* is still defined by equation (2.2), the generalized demand functions are

$$D_1(p_1, p_2) = \int_a^{w^*} f(x)dx = F\left(\frac{p_2 - p_1}{t_1 - t_2}\right) - F(a) \tag{3.2}$$

$$D_2(p_1, p_2) = \int_{w^*}^{b} f(x)dx = F(b) - F\left(\frac{p_2 - p_1}{t_1 - t_2}\right) \tag{3.3}$$

These demand functions determine the profit functions

$$\pi_1(p_1, p_2) = (p_1 - c)[F\left(\frac{p_2 - p_1}{t_1 - t_2}\right) - F(a)] \tag{3.4}$$

$$\pi_2(p_1, p_2) = (p_2 - c)[F(b) - F\left(\frac{p_2 - p_1}{t_1 - t_2}\right)] \tag{3.5}$$

and the profit-maximizing conditions

$$f\left(\frac{p_2 - p_1^*}{t_1 - t_2}\right)\frac{p_1^* - c}{t_1 - t_2} = F\left(\frac{p_2 - p_1^*}{t_1 - t_2}\right) - F(a) \tag{3.6}$$

$$f\left(\frac{p_2^* - p_1}{t_1 - t_2}\right)\frac{p_2^* - c}{t_1 - t_2} = F(b) - F\left(\frac{p_2^* - p_1}{t_1 - t_2}\right) \tag{3.7}$$

Equations (3.6) and (3.7) show that an increase in price has two effects: profits are lost from the marginal consumers who switch firms (the left-hand side of equations (3.6) and (3.7)), while profits from the consumers who are not on the margin increase (the right hand side of equations (3.6) and (3.7)). Profit maximization requires choosing a price such that these effects perfectly offset one another. Equations (3.6) and (3.7) are equivalent to equations (2.9) and (2.10) when $f = 1$ on $(0, 1)$, the case discussed in the previous chapter.

Although the formulas in equations (3.6) and (3.7) provide some intuition behind price-setting behavior, they are not particularly useful in solving the model. This is because many specifications of the wage distribution will not yield well-defined equilibria. Even a simple linear distribution of the form $f(x) = mx+b$ introduces complicated quadratics into the best response functions, leading to the possibility of zero, one, or multiple solutions. Nevertheless, we can easily allow wages to be uniformly distributed on an interval (a, b) other than the unit interval discussed in sections 2.1 through 2.3. Following the same procedure as before, we find that the optimal prices are

$$p_1^* = \frac{\Delta}{3}(b - 2a) + c \qquad\qquad p_2^* = \frac{\Delta}{3}(2b - a) + c \tag{3.8}$$

where Δ again denotes the time cost differential $t_1 - t_2$. Assume b exceeds $2a$, so that both firms make a profit in equilibrium (this condition is also necessary to ensure that the marginal consumer's wage falls inside the interval (a, b)). The equations in (3.8) simplify to the equations in (2.11) when $a = 0$ and $b = 1$, the unit interval case discussed in Chapter 2. These price equations determine the wage of the marginal consumer, which equals $(b+a)/3$. The equilibrium profits are

$$\pi_1^* = \frac{\Delta}{9} \cdot \frac{(b - 2a)^2}{b - a} \qquad\qquad \pi_2^* = \frac{\Delta}{9} \cdot \frac{(2b - a)^2}{b - a} \tag{3.9}$$

The firm with the high time-cost (firm 1) makes the lower profit, as before. The profit ratio between the two firms is

$$\frac{\pi_2^*}{\pi_1^*} = \left(\frac{2b - a}{b - 2a}\right)^2 = \left(\frac{2L + a}{L - a}\right)^2 \tag{3.10}$$

where L equals the length of the interval $b - a$. The derivative of this ratio with respect to a equals

$$\frac{\partial(\frac{\pi_2^*}{\pi_1^*})}{\partial a} = 6\frac{(2L + a)L}{(L - a)^3} > 0 \tag{3.11}$$

This equation states that the ratio of profit between the two firms grows as the wage interval moves higher. The larger profit ratio will drive firms to adopt the low-time cost technology as wages rise, as I show in the next section.

		Firm 2	
		t_{min}	t_{max}
Firm 1	t_{min}	0,0	$\frac{4}{9}\Delta, \frac{1}{9}\Delta$
	t_{max}	$\frac{1}{9}\Delta, \frac{4}{9}\Delta$	$0, 0$

Table 3.1: Payoffs for choice of time cost, wages distributed uniformly on a unit interval

3.2 Allowing firms to choose their time costs

To analyze how firms react when the wage interval moves upward, we need to allow the firms to choose the time cost consumers pay when using their products. Suppose that there are two possible time costs, t_{min} and t_{max}, and let Δ denote the difference between them $(t_{max} - t_{min})$. If both firms choose the same time cost, they set prices equal to marginal cost and make no profit (see Appendix). The payoffs for the possible combinations of time costs under a uniform distribution of wages on the unit interval are listed in Table 3.1.

No pure strategy equilibrium exists. If firm 1 knew with certainty that firm 2 will choose the low time cost, firm 1 would pick the high time cost and make the small profit. If firm 1 instead knew that firm 2 was picking the high time cost, firm 1 would choose the low time cost and make the large profit. The two firms therefore play mixed strategies in equilibrium. Suppose that firm 2 sets its time cost equal to t_{min} with probability σ. Firm 1's expected profit from playing t_{min} is then $\frac{4}{9}\Delta(1-\sigma)$, and its expected profit from playing t_{max} is $\frac{1}{9}\Delta\sigma$. These two expected profits must be equal for firm 1 to randomize, and they are equal if and only if $\sigma = .8$. Analogous reasoning shows that firm 2 randomizes if and only if firm 1 picks t_{min} with probability equal to .8. We conclude that each firm chooses the low time cost with probability .8 in equilibrium.

Now suppose that the wages are distributed uniformly on an interval (a, b), with $b > 2a$ as in Section 3.1. The payoffs are determined by the profits listed in equation (3.9) and are

		Firm 2	
		t_{min}	t_{max}
Firm 1	t_{min}	0,0	$\frac{\Delta}{9}\frac{(2b-a)^2}{b-a}, \frac{\Delta}{9}\frac{(b-2a)^2}{b-a}$
	t_{max}	$\frac{\Delta}{9}\frac{(b-2a)^2}{b-a}, \frac{\Delta}{9}\frac{(2b-a)^2}{b-a}$	$0, 0$

Table 3.2: Payoff table for choosing time cost, wages distributed uniformly on an interval (a,b) with $b > 2a$

displayed in Table 3.2. Using identical reasoning as before, each firm chooses the low time cost with probability

$$\sigma = \frac{(2L + a)^2}{5L^2 + 2aL + 2a^2} \tag{3.12}$$

where L again denotes the length of the interval. σ is graphed in Figure 3.1 for $L = 3$.

3.3 Discussion

In this chapter I use concepts from elementary game theory to derive an expression for the probability that the firms choose the low time cost. As is apparent from Figure 3.1, the firms choose the low time cost technology more often when the wage interval moves higher. One can show this result analytically by differentiating σ with respect to a:

$$\frac{\partial \sigma}{\partial a} = \frac{6(b - 2a)(a + 2L)L}{(2a^2 + 2aL + 5L^2)^2} \tag{3.13}$$

This expression is positive since we assumed $b > 2a$.

Given our interpretation of the firms as representative of entire industries, it seems contrived to use game theory to derive this result. However, this methodology makes sense

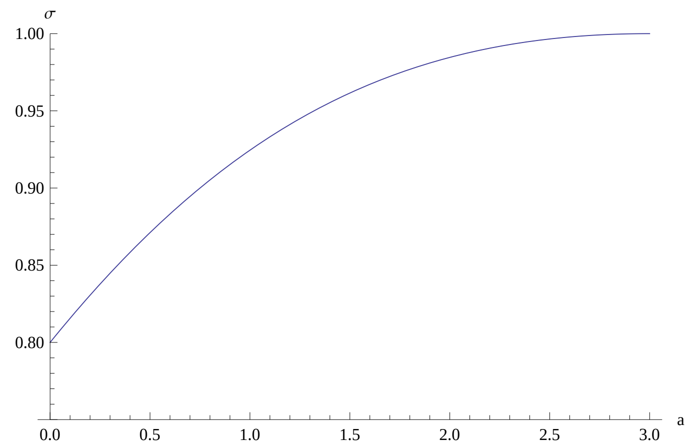

Figure 3.1: Probability of playing the low time cost as a function of the lower bound of the wage interval a

when thinking about entry into the food market: consumers earning high wages find it more costly to cook at home and are more willing to pay to save time; an entrepreneur entering the food market would therefore be more likely to open a restaurant than a grocery store when wages increase.

The marginal wage equals $(b+a)/3$, which is $2a/3+L/3$ for a wage interval of fixed length L. This expression shows that the marginal wage grows slower than the wage distribution as a whole: a 1 unit upward shift in the wage distribution causes the marginal wage to grow by only $2/3$. In words, fewer consumers find it worthwhile to consume the high-time cost good as their wages grow. This has important implications for understanding obesity: if the low time cost good causes weight gain, the model predicts consumers would become heavier as wages rise.

Chapter 4

An Empirical Test

4.1 Introduction

In this chapter I map the theoretical model developed over the previous chapters into a real-world example related to obesity, allowing me to empirically test the model's implications for the obesity epidemic. Recall that in the model I propose, consumers earning different wages purchase a single good from one of two firms. The time it takes the consumers to use the good varies across the firms, with one firm having a high time-cost and the other a low time-cost. In this chapter I analyze the implications of the model when the good is interpreted as a meal, the high time-cost firm as a grocery store, and the low time-cost firm as a fast food restaurant.

In Section 3.3, I showed how the low time-cost firms make a larger profit relative to high time-cost firms when wages are higher. The larger profit encourages firms to pick the low time-cost when wages are high. Applying this analysis to our example, the model predicts high-wage counties would have a larger fast food industry and a smaller grocery industry than low-wage counties. A simple way to measure the relative size of the two industries is to consider the ratio of fast food restaurants to grocery stores. In the next two sections I show that higher wages are correlated with a higher fast-food-to-grocery-store ratio in counties in the United States, as predicted.

4.2 Data

I obtained county-level data from 2008 on the number of fast-food restaurants and grocery stores in the United States from the US Department of Agriculture's (USDA) Food Atlas. The Food Atlas' data originates from the Census Bureau's Business Register, which collects and classifies records on business transactions occurring within the United States. Fast-food restaurants are defined as meal-serving establishments where customers pay before eating. Grocery stores are defined as establishments primarily engaged in retailing a general line of food. Convenience stores and large general merchandize stores that also retail food (e.g. supercenters and warehouse club stores) are excluded from the available measure of grocery stores.

I combined the information on food stores with county-level wage data available from the US Bureau of Labor Statistics and county-level demographic data from the US Census Bureau. The wage data come from the Quarterly Census of Employment and Wages, which uses quarterly tax reports to compile a census of 97% of nonfarm payrolls. I used the reported average weekly wage of all nonfarm employees in my analysis. Wage data from 99.5% of U.S. counties were available. The demographic data come from the Census Bureau's Population Estimates Program, which uses data for births, deaths and migration to estimate changes in the population of U.S. locales between the decennial census.

Summary statistics for the dataset are presented in Table 4.1. The weighted average of fast food restaurants per 1000 residents was .716, with 88% of observations falling within two standard deviations of the mean. 44 (1.4%) counties possessed no fast food restaurants, while the highest number was slightly over 14 (San Juan County, Colorado). The weighted

VARIABLES	mean	sd	min	max
Fast Food Restaurants per 1000 residents	0.716	0.294	0	14.31
Grocery Stores per 1000 residents	0.205	0.106	0	3.021
Fast-Food-to-Grocery-Store ratio	3.942	1.657	0	25
Average weekly wage	822.2	210.1	356	1944
% Non-Hispanic black	12.09	12.50	0	85.5
% Hispanic	15.48	16.40	.1	97.3
% Non-Hispanic white	65.70	21.53	2	99.4
Observations		3,135		

Table 4.1: Summary statistics for 2008 county level data (weighted by 2010 population)

average of grocery stores per 1000 residents was .205, with 86% of observations falling within two standard deviations of the mean. 55 (1.7%) counties reported no grocery stores in 2008, while the highest number was slightly over 3 (Yakutat County, Alaska). The weighted average fast-food-to-grocery-store ratio was about 4, with 90% of observations falling within two standard deviations of the mean. The highest ratio of fast food to grocery stores was 25 (Brookings County, South Dakota). The average weekly wage in 2008 for nonfarm employees was $822, with 99% of observations following within two standard deviations of the mean. The lowest average weekly wage was $356 (Petroleum County, Montana), while the highest was $1944 (New York County, New York).

Approximately 12% of the population were Non-Hispanic blacks. 77 (2.5%) counties reported that 0% of their population was Non-Hispanic black, while the highest percentage was 85.5 (Jefferson County, Mississippi). 15.5% of the population was Hispanic. The lowest percentage of Hispanic residents was .1 (Boyd County, Nebraska; Slope County, North Dakota; Hanson County, South Dakota) and the highest percentage was 97.3 (Starr County, Texas). Approximately 66% of the population was Non-Hispanic white. The lowest percentage was

2 (Starr County, Texas) and the highest percentage was 99.4 (Slope County, North Dakota).

4.3 Estimation

According to the theoretical model developed in the previous chapters, the average consumer in a high-wage county demands more fast food and fewer groceries than an average consumer in a low-wage county, *ceteris paribus*. As a result, an entrepreneur entering the food market in a high-wage county finds it more profitable to start a fast food restaurant than a grocery store. We therefore predict higher county wages will be correlated with a fast food industry that is large relative to the grocery industry.

To test this prediction, I estimated how the log of the average weekly wage in a county affects that county's ratio of fast food restaurants to grocery stores after controlling for state fixed effects and the county's demographic composition. Explicitly, the model I estimate can be written as

$$\frac{FF_i}{groc_i} = \beta_0 + \beta_1 \cdot \log(wage_i) + controls_i + \epsilon_i \tag{4.1}$$

FF_i denotes the number of fast food restaurants in county i, $groc_i$ denotes the number of grocery stores in county i, $wage_i$ denotes the average weekly wage in county i, the controls include county i's racial composition and a dummy variable for each state, and ϵ_i is a random error term. I use the ratio of fast food restaurants to grocery stores as the dependent variable because it is a straight-forward way to capture the relative size of the two industries of interest. This ratio may be subject to measurement error, an important concern if the measurement error is correlated with the right-hand side variables or with ϵ_i (see Section 4.5). Nevertheless the dependent variable is intuitively appealing and nicely matches the theoretical results derived earlier, which is why I use it in the regression. Alternative measures of relative industry size, such as data on expenditures, were unavailable at the county level. Wages are entered in logs to correct for skewness in the distribution and to allow for a percentage change interpretation of the coefficient. Entering wages into the regression in level form did not substantively change the results. The demographic and state control variables are used to account for factors that jointly influence food preferences and wage outcomes. The demographic makeup of a county affects its cultural and economic environment, influencing residents' earnings and predisposition toward fast food. Cultural and economic environments also vary across regions of the country, providing justification for including the state fixed effects. State fixed effects are also included to control for public policies that might influence the ratio of interest, such as the taxes on unhealthy foods some states have introduced to combat obesity. Although controlling for these sources of endogeneity is important, it is possible that other omitted variables cause the coefficient on wages to be unidentified. I discuss these issues further in Section 4.5.

I estimated the coefficients of the model in (4.1) using generalized least squares, weighting each observation by the county population. Generalized least squares is more efficient than ordinary least squares when using aggregated data (see Wooldridge (2009), Chapter 8). The 55 counties (1.7%) that had no grocery stores were excluded from the regression.

4.4 Results

The coefficient estimates for this model are reported in table 4.2. A 1% increase in county wages is correlated to a 1.5 unit increase in the ratio of fast food restaurants to grocery stores. This is a large effect: a 1% increase in wages for the average county ($8.25 per week) would increase the ratio of fast food restaurants to grocery stores in the average county by almost 40% (from 4 to 6.5). The unweighted average county had 20 grocery stores and 70 fast food restaurants, so the estimated coefficient implies that a 1% increase in wages would correspond to 30 more fast food restaurants or 6 fewer grocery stores in an average

VARIABLES	Fast-Food-to-Grocery-Store Ratio
log(wage)	1.510***
	(0.268)
% Non-Hispanic black	-0.017***
	(0.008)
% Hispanic	0.0300***
	(0.008)
% Non-Hispanic white	0.0300***
	(0.007)
Observations	3,079
R-squared	0.326

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4.2: GLS estimates of the empirical model

county. The 95% confidence interval for the coefficient on wages is (.984, 2.04); even the lower bound of this interval implies that wages have a significant effect on the ratio of fast food restaurants to grocery stores.

The coefficients on the demographic variables suggest that moving from an all black county to an all white county is correlated with a five-fold increase in the fast-food-to-grocery-store, after controlling for wages. The percentage of the county population that is Hispanic is also correlated with a higher fast-food-to-grocery-store-ratio. The model explained approximately 32.6% of the variation in the county-level ratio of fast food restaurants to grocery stores.

4.5 Discussion

The positive relationship found between wages and the fast-food-to-grocery-store ratio is consistent with the fundamental predictions of the theoretical model. However, these results must be interpreted with caution because of two important caveats. The first is an endogeneity problem: the wages earned by residents of a particular county are equilibrium outcomes determined by factors that also affect that county's demand for fast food and groceries. For example, consumers located in a county with a poor education system would tend to earn lower wages; these consumers might also not appreciate the health consequences of consuming fast food, leading to an abnormally high demand for it. This implies that the correlation between the error term and the wage term is negative (wages and education are positively correlated, and higher education reduces the fast-food-to-grocery-store ratio), biasing our estimate of the coefficient on wages downward. Population density also plays a role, since the population density of a county affects both its wages and its fast food consumption. Rural counties are poorer and can support fewer fast food restaurants than urban counties, biasing our estimate of the coefficient on wages upward (population density and wages are positively correlated, while a higher population density increases the ratio of fast food restaurants to grocery stores). Moreover, since these biases have the opposite sign it is difficult to predict whether our estimate of the wage effect is too large or too small. To properly correct for these problems, it would be necessary to compile a panel dataset containing multiple observations on individual counties over time. A fixed effects model could then be used to eliminate time invariant components of the error term, such as the education system or economic structure unique to a given county. Unfortunately, such data were unavailable for this analysis.

The second problem is the possibility of measurement error in the dependent variable. Because there exists substantial heterogeneity in the size of grocery stores, the dependent variable may not be an accurate measurement of the ratio of interest. Because large "superstore" vendors like Walmart and Target are excluded from the grocery store variable, the reported ratio may larger than the actual size of the fast food industry relative to the grocery industry. This could especially be a problem in low-wage counties where a larger percentage of grocery shopping occurs at low price superstore vendors. The correlation of the measurement error with wages would tend to bias our estimate of the coefficient on wages upward. A more accurate dependent variable might be expenditures at fast food restaurants relative to expenditures at grocery stores, but county-level expenditure data were unavailable for this analysis.

These empirical caveats suggest that better data are necessary before we can conclude there is a causal relationship between wages and the prevalence of fast food restaurants relative to grocery stores. Even if it were possible to show such a link, there is still the matter of establishing the relationship between fast food and obesity. This has been an area of active research: Prentice and Jebb (2003) propose that the high energy density of fast foods make them prone to causing obesity, and Maddock (2004) demonstrate correlations between per capita fast food restaurants and obesity prevalence at the state level. Boone-Heinonen et al. (2011) use longitudinal data to show that fast food availability and fast food consumption are positively correlated. On the other hand, Jeffery et al. (2006) fail to find a relationship between the proximity to fast food restaurants and obesity in an individual-level dataset. Perhaps the more important empirical question is whether there is a direct connection between wages and obesity. On the surface, this claim seems inconsistent with the fact that obesity disproportionately affects minorities and those with low socioeconomic status (see Wang and Beydoun (2007)). However, the evidence underlying the relationship between obesity and poverty is predominately correlational. Moreover, it has not always been the case that people in poverty tended to be overweight. To properly establish a relationship between income and weight, it would be necessary to follow counties (or even individuals) over time to see how *changes* in wages affects the prevalence of obesity. Even though impoverished minorities might tend to be more obese than wealthy whites in a cross-section, increasing the wages of either group may still lead to weight gain.

In summary, the findings of this chapter are consistent with the results of the theoretical model. However, better data is necessary before we can conclude that a causal relationship exists between wage growth and the relative size of the fast food industry. Moreover, the direct relationship between wages and obesity remains to be established.

Chapter 5

Conclusion

The obesity epidemic is one of the primary health concerns the world confronts today. In this paper I developed a theoretical model that showed how wage growth, by decreasing the relative price of low time-cost goods like fast food, could contribute to the epidemic. I then tested the theoretical model's fundamental implication by estimating how wages are correlated to the relative prevalence of fast food restaurants and grocery stores in counties in the United States. Although I found a positive correlation consistent with the theoretical predictions of the model, issues with estimation like endogenity and measurement error prevented me from firmly establishing a causal link.

The work presented here provides a framework for thinking about how the obesity epidemic could be a byproduct of economic growth. In so doing, the model offers insight into the growth of obesity over time and across countries. On the one hand, the model could be viewed as discouraging because it implies a tradeoff between public health and economic progress. But even though it might be impossible to break the link between wages and the demand for low time-cost food, firms in the meal industry are currently developing healthier, more appetizing, fast food options. New products such as these could be crucial to combating the obesity epidemic in the future.

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Appendix

Proposition 1. *Suppose wages are uniformly distributed on a finite interval and that consumers have identical utility functions described by equation* (2.1)*. Assume that the two firms supplying the market produce at constant marginal cost* c *and have identical time costs associated with their goods. Then a unique Nash equilibrium exists in which the firms both charge a price equal to* c*.*

Proof. Let p_1 and p_2 denote the prices charged by the two firms in equilibrium and let $U_i = v - wt - p_i$ represent the utility received from consuming at firm i, where t denotes the time cost that is assumed to be equal at both firms. To see that perfect competition is a Nash equilibrium, notice that if $p_2 > p_1 = c$, then $U_1 > U_2$ for all values of w. This implies firm 1 serves the entire market while firm 2 serves no customers. If $p_2 < p_1 = c$, firm 2 operates at a loss. Thus if firm 1 charges a price equal to marginal cost, firm 2 can do no better than charging this same price. This holds true when the roles of the two firms are switched, implying that neither firm has an incentive to deviate from setting price equal to marginal cost if the other firm is doing so.

To see that this equilibrium is unique, suppose firm 1 charges price $p_1 > c$. Then firm 2's best response is to charge $p_1 - \epsilon > c$ where ϵ is an arbitrarily small positive number. This is because charging a price equal to $p_1 - \epsilon > c$ implies that $U_2 > U_1$ for all values of w, ensuring that firm 2 serves the entire market at a profit. Reversing the roles of the two firms, we see that if $p_2 > c$ then firm 1's best response is to choose a price equal to $p_2 - \epsilon > c$.

An equilibrium can therefore not exist in which either firm charges above marginal cost, because as long as one firm's price exceeds marginal cost the other firm has an incentive to infinitesimally undercut. The only equilibrium in which neither firm has an incentive to deviate given the other firm's choice of price is when both charge a price equal to c, as claimed.

$\square$