Economics Is a Science of Time Saving: The First Tentative Model (2016)

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21 November 2016

Preliminary draft, 11-21-2016. All comments are welcome.

Economics Is a Science of Time Saving: The First Tentative Model

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Abstract: Time might be the scarcest resource for every individual. Time saving could be one of a few specific starting points of Economics. According to the new attribute theory that is based on Lancaster's attribute theory, the paper constructs a linear programming model with an objective function of time saving that is independent of any utility function. Then the demand function of the time saving good can be derived with a programming method, which is different from the parametric and typically non-parametric methods. Because some data was unavailable, the empirical research of this paper cannot directly derive the demand function from the programming model. Thus another method is used to derive the demand function and the predictive power of this function is at least as good as that of the most common econometric models. Further, as a basic human behavior, time saving could be generalized to other fundamental theories of Economics, especially the long-run growth theory. Therefore, in the ultimate meaning, the conclusion is that Economics is a science of how to save time and time saving might be a milestone that will shift Economics towards a modern science.

Key words: new attribute theory, time saving function, demand function
JEL: B10, B23, C61, D01, D11

1. Introduction

Probably what you want most is freedom while what you have only is time. Freedom is infinite but your time is finite. You cannot keep or directly buy time and in some key situations you also cannot acquire any extra time in any form in any market besides the normal time you have. Therefore, time might be the scarcest resource for every individual.[1] Consequently, in all other situations, you will attempt to save time. In terms of consumption behavior, it usually refers to indirectly buy time, namely buy time saving goods.[2]

Although it is well known that Economics is a science of how to allocate scarce resources (Krugman, 2012, p. 6; Mankiw, 2015, p. 4; Samuelson and Nordhaus, 2010, p. 4), few people have built formal model to discuss what the scarcest resource is.[3] The major reason could be, as the theoretical foundation of mainstream Economics, the utility theory is not compatible with any specific or

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[1] Although a study showed that an Amazonian tribe had few concepts of time in its language and calendric system (Sinha, etc. 2011), but it cannot reject for most people in our society that time is a scarce resource and time saving is one of the objectives in their behavior.

[2] We do not discuss the time saving services here. But the theory and method of this paper can be applied to both the goods and services.

[3] Lester Brown (2011) had a presentation of "The Planet's Scarcest Resource Is Time". But there was no formal model to express this idea.

straight objective function of how to save some resources.[4] In real purchasing behavior, most probably a consumer will transfer several of her preferences into several specific objectives for a good. But the utility theory has to assume all the preferences or all specific objectives to be transformed or reduced into one continuously differentiable objective function of utility, which is not a concrete and straight objective. Because if there are at least two objective functions or the function is not continuously differentiable in the system of utility maximization, then the system cannot be optimized by taking derivative (Mas-Colell, Whinston and Green, 1995, p. 47; Jehle and Reny, 2011, p. 24). To thoroughly review the utility theory is beyond the scope of this paper. Stigler (1950, I and II) already presented a classical criticism on it. This paper only focuses on explaining the incompatibility from a particular technical perspective. The assumptions of continuity of preferences and utility function might be a major intrinsic defect of utility theory.

A specific objective function or a system of objective functions, transferred from a consumer's preferences, could be discrete or lexicographic, but the utility theory can only deal with a continuously differentiable objective function subject to some constraints and obtain an analytical solution of the related demand function[5] by taking derivative. Thus, the mainstream economics neglects or ignores the numerous existing discrete objective functions in the real world. The reason probably is that it is unable to obtain an analytical solution from these objective functions.[6] If we could explore a new method that would build a model to simulate not only continuous but also discrete objectives with some constraints and solve the model, in which the solution is not necessarily an analytical solution, then it might become a more generalized theory than utility theory.[7] Further, because the utility theory is built on a serial of strict assumptions and if we do not have to depend on this theory, then it means that we do not have to depend on the strict assumptions.

The purpose of this paper is twofold. First, we construct a specific objective of time saving to maximize the time saving function (rather than any utility function) in a math programming model

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[4] Although all resources are usually not in the objective function but in the constraint conditions of a system of utility maximization, by Duality we can set up an objective function of resource saving subject to some constraints, including a fixed value of utility. Thus, resource saving can be an objective function. Indeed, one of the differences between utility theory and the modeling method of this paper is that the utility will present in neither the objective function nor the constraints.

[5] If there are more than one good in the optimization model, then each good has a demand function. Thus the solution is a system of demand functions. For simplicity, this paper only discusses the situation of one demand function for one good in most parts.

[6] It seemed that nothing could guarantee that every demand function in real world was an analytical solution of a utility maximization system.

[7] Another possible relationship between the new model and utility theory can be explained by that between friends and friendship. The preferences of making friends can be lexicographic, the objective function of how many friends a person will make should be discrete, and the demand function of friends could be derived from the programming model by maximizing this objective function with some constraints; while the objective function of getting friendship may be continuous and differentiable, which can be regarded as the utility function. But the point is that making friends can be an economic issue with other concrete and straight issues in the constraints, while the utility of getting friendship from friends might not be a pure economic issue. The latter could be a psychological issue or just an assigned number without any specific meaning, or a mixed issue of economics, psychology, and a meaningless number. However, if we are able to derive a demand function of friends from the objective function of making friends in a programming model, then we do not need the objective function of getting friendship and the related model.

and then present a method to derive the related demand function. The modern math programming can solve a large number of economic models in the real world, including discrete or lexicographic models, while the utility theory can only solve differentiable models.

Second, we attempt to set up time saving as one of a few starting points of Economics.[8] If we do not have to depend on the utility function and its strict assumptions, then Economics is not necessarily based on the starting point of utility theory. On the other hand, at least in principle, we can simulate a complete process from a consumer's preferences for a good to a specific objective function or a system of objective functions by math programming and then derive the demand function under constraints. Further, since Economics is a science of scarcity and if it is true that time is the scarcest resource, then time saving could be an operational starting point of Economics.[9] Therefore, if the demand theory could be, at least, partly built on the objective of time saving, then Economics would be a science of the real world.

Even though we accept that time saving is the starting point of Economics, it does not mean that every consumer has the objective of time saving at any time. A consumer has a lot of specific and straight objectives in real world while time saving is only one of them. But probably it could be a fundamental or an ultimate objective. In the daily life, the objective of time saving is usually roundabout, i.e., we sacrifice part of our whole time in working and earn income to save more time for other objectives.

The structure of this paper is as follows. Section 2 is a literature review to explore the classical thinkers' contributions on time saving in Economics and develop Lancaster's attribute theory into a new attribute theory. Then it briefly answers a question that why attribute theory couldn't be the foundation of Economics. Section 3 builds a linear programming model of time saving and derives a demand function with a non-parametric method from this model. A case study presents the empirical evidence in Section 4 to support the theoretical framework of the programming model based on a law of time saving. Section 5 concludes the paper and provides some suggestions for further research.

2. Literature review

2.1 **Economic Thoughts of Time Saving**

Although time saving has been neglected as the foundation of economic thought until recent years, it is one of the insightful findings in Economics. At latest in one of Smith's works, *The Wealth of Nations*, time saving had implicitly served a key role in his theory. When Smith explained the advantages of division of labor, the initiative of time saving was coined in the book:

> *"This great increase of the quantity of work which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different*

[8] It's better to say that time saving is not a starting point but an objective of human behavior. But from the methodological perspective, we can also take time saving as the starting point for economic research.

[9] Certainly, maintaining subsistence is the premise of human behavior and it is also a starting point of Economics.

circumstances; first, to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many" (Smith, 1776, p. 17).

Here Smith directly concluded that the second advantage of division of labor was "to the saving of the time". Moreover, if we further think about the other two advantages, "to the increase of dexterity" and "to the invention of a great number of machines", we can find that these two advantages also have an unambiguous objective of improving the productivity within a given time. Therefore, we are able to conclude that in Smith's thoughts one of the significant consequences from division of labor is to save time. Or put another way, because a successful consequence usually originates from its objective, thus time saving could also be an objective of division of labor.

Karl Marx is another thinker of Economics who really emphasized the importance of time saving. In one of his works, he wrote:

"Economy of time, to this all economy ultimately reduces itself....Thus, economy of time…remains the first economic law on the basis of communal production. It becomes law, there, to an even higher degree" (Marx, 1857-61, p. 173).

Noticeably, time saving had explicitly played a critical role in Marx's thoughts and it cannot be overestimated how significant the time saving is.

However, after the utilitarianism became the mainstream of Economics, it was hard for the thought of time saving to return back to its central stage in Economics. Thus few thinkers had mentioned time saving as a systematic theory since the end of 19^{th} century. Mises may be one of them. But he only focused on the limitation of time:

"…it is obvious that labour is available only to a limited extent: the individual can only perform a certain amount of labour. Even if labour were a pure pleasure it would have to be used economically, since human life is limited in time, and human energy is not inexhaustible. Even the man who lives at his leisure, untrammelled by monetary considerations, has to dispose of his time, i.e., choose between different possible ways of spending it" (Mises, 1951, p. 164-165).

Because Mises didn't draw a conclusion on how to save time, he thus didn't develop the theory initiated from Smith and Marx. Generally speaking, the economic discussion on time saving in 20th century has been directed to how to allocate the time (Becker, 1965; Heckman, 2014) but not how to save time. It is true that allocating time is also one of the methods of saving time, but it is necessary to re-emphasize the key role of time saving in the theory of Economics.[10]

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[10] Zhu (2011) reported in a seminar that time saving was a fundamental economic behavior and provided theoretic method of how to optimize the objective function of time saving and how to derive a related demand function. But at that time, no data was available to be applied in the method.

Although some research found that the households would buy more time saving goods as income increased, especially the convenient foods to save time (Senauer, Sahn, and Alderman, 1986; McCracken, and Brand, 1990; Kennedy and Reardon, 1994), it still held utility as the theoretical basis and did not realize that time saving could be an independent objective. Thus we attempt to switch the theory of utility to that of attribute, in particular the attribute of time saving and derive the demand function of time saving goods from the time saving attribute.

2.2 Consumer's Specific Objectives: Not Utility but Attributes

From the objective of time saving, utility is not a suitable foundation to incorporate time saving into the economic theory since time saving is a concrete and empirical objective of consumer that is entirely not like the utility, which is indirect and unempirical.[11]

Fortunately, Lancaster (1956) proposed a well-known attribute theory[12] that what the consumer actually bought from the goods were the attributes of these goods. For time saving goods, saving time is one of their attributes or a primary attribute. Since time is observable, measurable and comparable across all individuals, it is better to accurately calculate how long of the time that these goods can save than to arbitrarily assign a level of utility for the same goods to the consumer. Therefore, at least for the goods with the unique attribute of time saving,[13] utility theory is not necessary or even meaningless. Instead, we can simply measure the saved time of those goods because this is the whole objective for consumer to buy them and nothing is missed.

Different from Lancaster's attribute theory, which is still built on the utility theory, this paper will not use the concept of utility but only apply attribute to describe the goods and the consumer objectives. Thus the theoretical foundation of this paper is "slightly"[14] different from Lancaster's theory and it could be coined as the new or modified attribute theory. But for brevity, we call it the attribute theory

[11] Stigler (1950 II) forethoughtfully concluded that the utility could not be empirically tested. He criticized that "The (third) criterion of congruence with reality should have been sharpened - sharpened into the insistence that theories be examined for their implications for observable behavior…. Not only were such implications not sought and tested, but there was a tendency, when there appeared to be a threat of an empirical test, to reformulate the theory to make the test ineffective". Moreover, some researchers already found that the mainstream theory might actually not be based on the utility (Dardi, 2008) and some others tried to build a theory without the utility function (Dominique, 2007 and 2008). However, none of them presented any empirical evidence to demonstrate it was possible to abandon the utility function and derived a demand function in an alternative method. Attema et al. (2010) and Attema et al. (2015) provided a new method to measure intertemporal choice and temporal discounting of money without the information of utility. But these studies did not have an objective of time saving and were not a method to derive a demand function.

[12] The Lancastrian term is characteristic instead of attribute. But attribute is a more common term in modern theory for the feature of goods and characteristic for that of individuals. This paper does not borrow the whole Lancastrian theory but only borrow the idea of attributes of goods.

[13] If a good has more attributes that cannot be omitted and we have more objectives on it, then we can apply a multi-objective programming model to simulate the consumer's behavior.

[14] We can also say that the theoretical foundation of this paper is "significantly" different from Lancaster's attribute theory because the former is not based on utility theory while the latter is.

in most cases.[15]

2.3 "No Programming No Attribute"

A consequent question of the above discussion is why time saving couldn't be one of the starting points of the mainstream Economics, or more generally, why the attribute theory couldn't be the foundation of Economics while the utility is?

The theory and technique of math programming had not been formally developed before 1940s (Dorfman, Samuelson and Solow, 1987, p. 3). Taking derivative has been almost the only method to optimize the utility model since the utility theory has been established in 19th century. For this reason, Economics before 1940s had no choice but applied taking derivative to solve the model for a solution, especially for an analytical solution. And because taking derivative depends strictly on the continuous and differentiable objective function, the early economic thinkers had to assume not only the existence but also the continuous differentiability of utility function. Further, since the analytical solution of demand function (not any empirical demand function) can be obtain from the utility function, thus it seems that the utility theory is complete and aesthetic. As a result, the progress for setting attribute theory as the fundamental economic theory had been delayed.

After 1940s, it turns out that math programming is a more powerful method than taking derivative in modeling the real world, because the latter can only deal with the continuously differentiable function whereas the former can compute both the continuous and discrete functions. Thus it is possible to bring attribute theory back to the foundation of Economics for the reason that it might be its original position in Economics. Therefore, it can be viewed that if there was no programming method then the attribute theory could not be a mainstream theory, i.e., "no programming no attribute".

3. Time Saving Model and Demand Function

The theoretical framework of this paper includes two parts. The first is a programming model to maximize the saved time. Although only a simple model is presented here, it doesn't mean the complicated models cannot be treated by the programming technique. Indeed, math programming can process various types of preferences and consumption models (Paris, 1991; McCarl and Spreen, 2004). The second part is a method of how to empirically derive, not estimate, a demand function from the programming model. The following two subsections will elaborate the two parts successively.

3.1 Optimization of Time Saving

[15] Accordingly, an apparent problem arises for the attribute theory is how to identify all the attributes of each good and all the objectives of each consumer for that good. Unlike the utility theory that always assumes a utility function without testable empirical evidence, the attribute theory will depend on the field surveys to figure out the good's attributes and consumer's objectives. Till present, however, it seems few studies have been done on such surveys.

Based on the new attribute theory, the time saving function can be set up straightly with the method of math programming.[16] For simplicity, we use the linear programming approach to build and solve the model. For ease of understanding, we don't use the notation of summation. Thus, the objective function and the constraints can be written as

$$\underset{i,j,\dots,r}{Max} T = (t_{11} + t_{12} + \cdots + t_{1i}) + (t_{21} + t_{22} + \cdots + t_{2j}) + \cdots + (t_{m1} + t_{m2} + \cdots + t_{mr})$$

$$\text{s.t. } ip_1 + jp_2 + \cdots + rp_m \le B \qquad \text{[Model 1]}$$

$$t_{mi}, t_{mj}, \dots, t_{mr} > 0$$

$$p_1, p_2, \dots, p_m > 0$$

$$i, j, \dots m \dots, r = 1,2,3\dots,$$

where T is the total time saved from using all the time saving goods; t_{11}, t_{12}, …, t_{1i} denote the time saved from using the first, second, till the *i*-th unit of the identical good *1*, respectively, since the time saving effect of each unit of the good is different; t_{21}, t_{22}, …, t_{2j} denote the time saved from using the first, second, till the *j*-th unit of the identical good *2*, respectively; and so on till the time saved from using the good *m* in the number of *r*; p_1, p_2, …, p_m are the price of good *1*, good *2*, till good *m*;[17] the consumer's expenditure on all the time saving goods is subject to the budget *B*; all variables are positive; in some cases, the quantity of each good or some goods must be integer.

The existence of a solution for this model is guaranteed by two facts. First, the budget *B* is limited and the price is positive. If the budget is unlimited, then the consumer will buy unlimited quantity of time saving goods. Thus the total saved time *T* will also be unlimited. But due to the assumptions of the limited budget and positive price, it will not happen. Second, the marginal effect (not the marginal utility) of each time saving good is diminishing at a certain quantity of that good. This is an empirically verified fact because every time saving effect of each unit of good is strictly observable, measurable and comparable across all consumers and all goods. If the consumer cannot save any time by purchasing one more unit of that good after a certain quantity, then the programming model will have a solution. These two facts are not the necessary but the sufficient conditions to guarantee the existence of solution. For conciseness, we will not discuss the necessary conditions.

In this model, if we have the data of price, budget, and the time saved from using each unit of the goods, then we are able to compute the quantity of every kind of goods purchased by the consumer

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[16] It is true that this model applies only to the goods that their unique attribute is time saving (we use the multi-objective programming model for multi-attribute goods). It might be also true, however, that there was no one universal or panacea objective function that could empirically get all kinds of consumers' behaviors done once for all, though this function or this method seemed elegant. Generally speaking, even a theory is universal, it doesn't mean any objective function within this theory must also be universal. Probably the consumers' objectives should be preference-specific and product-specific. That suggests we cannot set up a universal objective function for all consumers' behaviors like utility theory, but need to simulate the real world in a concrete context, i.e., building a model for one kind of consumers' behavior each time.

[17] If the price is changed for marginal unit of the same good, then the constraints of the model should be slightly adjusted. But the nature of the whole model keeps unaffected.

and the total time saved from using these goods. We should notice that the purchasing quantities or the demand of the goods are not directly shown in the objective function. But programming software will report the quantity of all goods.

A major problem in this model is how to quantify the budget on the time saving goods. We have two methods to solve this problem. First, since all programming models have the property of Duality and if the model is set as minimizing cost of time saving goods， then we can remove the budget from the constraints. But instead, we have to assign a value of how much time (not any amount of utility) we want to save.[18] Thus the problem can be solved. Second, for a time saving objective, it is straightforward to set a maximization model. Therefore we use another method to calculate the budget and such a method may be only suitable for the goods with the only attribute of time saving, because we can find the consumer's budget share for these goods. We will elucidate this method in subsection 4.3. The second method is very simple, but the prediction of demand function derived from it can be significantly verified.

3.2 The Derivation of Demand Function: A Special Non-parametric Method

After setting up the programming model, we are able to derive a demand function in three steps. First, calibrate the model in one year, if the annual data is used and the data of budget are available, and solve it. Then save the result of consumer's purchasing quantity, because it is the demand of the good in this year.

Second, based on the calibration year, change the price and the budget[19] of the good simultaneously to another year, then run the model again to solve for the consumer's purchasing quantity, and save it as well. Enumerate all possible prices and budgets in all years and solve all the related purchasing quantities, thus we obtain a group of vectors that represents the annual purchasing quantities.[20] It is the demand data but not in a form of a function.[21] For the pure demand theory, the results are complete. Because we obtain all the basic demand information and it is not necessary to have the form of a function. But if we need a function of that, we precede to the last step.

The third step is to run an econometric model with the demand data as the regressand and other variables as the regressors. Then we get a demand function.

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[18] For a certain amount of the saved time, the cost may be beyond the limit that the consumer can afford. But if we adjust the amount of the saved time, which is like a trial-and-error process, we could find an approximate minimum affordable cost.

[19] If there are more variables in the model, all of them should be changed simultaneously. Moreover, if the data of expenditure is directly based on that of consumption, it will be endogenous with the saved time, because the saved time is also directly from the data of consumption. As state previously at the end of Section 3.1, this problem can be solved. But here it is easy to explain the procedure of how to derive the demand function from this model rather than the model of cost minimization.

[20] To find a whole demand system, we still calibrate the model at one year first, then change the price and other variables of all goods simultaneously and solve all the related purchasing quantities, thus the results are a system of the annual demand.

[21] If we focus on the data of price and demand, we can draw a demand curve on the ground of two-dimension scattering points.

It is worth noting that in this paper we use the programming method to derive a demand function, which is neither a parametric nor a typically non-parametrical method. The mainstream parametric methods, including some non-parametrical methods, are used to empirically estimate, not derive, a demand function. The programming method, however, can be viewed as a special non-parametrical method to derive, not estimate, a demand function from a programming model. In a real world, it is hard to imagine that consumers apply estimation techniques to calculate their demand for even one good. Probably it is more realistic for consumers to form their demand from a simple programming model with the special non-parametric method. If it is the case, this programming method might be a better technique than the estimation ones in simulating the real world.[22]

Apparently, the above demand function is not an analytical solution from the programming model. It is aesthetic that if we could obtain such an analytical solution as it does in the utility theory.[23] But in reality, an analytical solution of the demand system might not exist.

Considering the relationship between the utility model and programming model, it is reasonable to conclude that utility model is a special case of programming model in that the former holds some strict assumptions, e.g., the utility function is continuously differentiable. But for many real economic facts, the discrete or multi-objective functions could not be modified in a procrustean way to a differentiable function, otherwise the results would have no concrete scientific meaning that is empirically testable.

4. A Real Case: from Time Saving Law to Demand Function

Although it is not easy to have complete datasets to apply the above programming model in finding a time saving demand function, we can start from a case study. A real case speaks a thousand examples, because it is from a tangible world. In utility theory we only have examples of utility functions. In the attribute theory, however, we had better not to accept any example of objective function and optimization model, but only accept real cases.

4.1 Data of Bike Possession in Rural China: 1978 to 1992

Despite the fact that some datasets of time using or time saving are available (Aguiar, Hurst, and Karabarbounis, 2012; McGuire and Popkin, 1990; National Bureau of Statistics of China, 2004), they are not sufficient to be applied in a programming model because there is almost no specific time saving goods related to the data. A simple way to run the programming model is to find a dataset of a good that it has a single attribute of time saving with its price, its amount that each household possesses, and the information of how long of the time it can save. However, it is hard to have all such data at present.

[22] It is true that a scientist of economics can be an observer of the real world to build econometric models in estimating the consumers' behavior. But it is also true or more important that we should directly understand the consumers' real behavior in the formation of demand first.

[23] A defect in utility theory is that all the analytical solutions of demand functions are not real demand functions. Indeed, in the mainstream Economics, all the real demand functions need to be estimated with econometric regression.

Probably we can use the annual data of bike possession per 100 households in rural China to partly satisfy the requirements of the programming model, even we have no information of the time that each bike saved for the usage by the households. Since the price data of bike is only available from 1978 to 1992, thus we have to limit the model in the same time period of 15 years.[24] Columns 1 and 2 of Table 1 present the possession and unit price of bike in rural China of that time period.[25]

Table 1. Household Possession and Unit Price of Bike, Household Net Income in Rural China, and the Results (1978-1992)

Year	Bike Possession per 100 Households (Unit) (1)	Average Unit Price of Bike (Chinese *yuan*) (2)	Total Expenditure of Bike (Chinese *yuan*) (3)=(1)*(2)	100 Rural Households Net Income (Chinese *yuan*) (4)	Share of Bike Expenditure over Net Income (%) (5)=(3)/(4)	Average Budget on Bike (Based on s=6.19, Chinese *yuan*) (6)=(4)*6.19	The Programming Demand (Unit) (7)=(6)/(2)
1978	30.73	159.00	4886.07	76686.40	6.37	4744.25	29.84
1979	36.20	156.04	5648.48	90741.12	6.22	5613.75	35.98
1980	36.87	147.03	5421.07	102880.02	5.27	6364.73	43.29
1981	44.41	146.17	6491.30	122932.04	5.28	7605.26	52.03
1982	51.50	142.48	7337.85	147496.00	4.97	9124.92	64.04
1983	63.41	140.53	8911.09	168231.39	5.30	10407.73	74.06
1984	74.48	136.78	10187.42	190119.48	5.36	11761.85	85.99
1985	80.64	125.34	10107.04	183936.20	5.49	11379.31	90.79
1986	90.31	129.39	11684.96	188032.92	6.21	11632.76	89.91
1987	98.52	136.62	13459.77	195446.11	6.89	12091.38	88.50
1988	107.49	127.00	13651.52	205057.03	6.66	12685.97	99.89
1989	113.43	123.63	14023.51	198489.79	7.07	12279.68	99.32
1990	118.33	117.12	13858.47	199566.34	6.94	12346.28	105.42
1991	121.64	120.10	14609.31	199725.85	7.31	12356.15	102.88
1992	125.66	124.27	15615.76	209759.21	7.44	12976.87	104.42
Average	-	-	-	-	6.19	-	-

Note: The base year of price and income is 1978.

Source: National Bureau of Statistics of China (1979-1993).

This dataset has two strong points for modeling simple behavior of time saving. First, bike usually had one primary attribute of time saving in rural China after 1978, though it may have other

[24] This dataset of 15 annual points may be not sufficient to run a regression model for the estimation of a demand function. In reality, however, sometime it is necessary to find a demand function for even a smaller dataset. Indeed, it is a great advantage of the programming model that it can derive a demand function in a very small sample size without theoretic defects.

[25] The Table A1 and A2 in Appendix report how to calculate the comparable price of bike and the net income of rural households.

attributes,[26] especially as a symbol of conspicuous consumption before that year. From 1978, every 100 households already had 30.73 bikes or nearly one thirds households had a bike. In spite of the fact that we could not confirm what relative percentage of possessing an expensive good among neighbors would bring conspicuous feeling or satisfaction for a household, 30.73% might be larger than that percentage and the possession of a bike could not give the household a great conspicuous satisfaction over the neighbors.[27] Thus we could consider bike from 1978 had only one attribute of time saving.

Second, until the middle of 1990s, it seemed that the most common means for daily passenger transportation was bike in rural China[28] and the household's expenditure on bike might be the largest part or nearly all of the whole expenditure on time saving goods.[29] Before 1990s, there almost were no buses in rural areas for daily transportation.[30] Even trucks and tractors were seldom used as the passenger vehicles.[31] Even though some rural households had motorcycles, the possession per 100 households of them was no more than 1.42 units before 1993 (National Bureau of Statistics of China, 1994) that was too low to replace the role of bike in daily transportation. Thus there were no major substitutes for bike in that situation. Moreover, there were no data to be evidence that from 1978 through 1992 the rural households spent some large expenditure on other time saving goods. Therefore, in the programming model bike could represent almost all of the time saving goods.

According to the two facts above that the bike had only one primary attribute of the time saving and, based on available dataset, the expenditure on bike was almost all the expenditure on time saving

[26] Some attributes, such as size and color, of the bike are not considered here. Because, first, these data were unavailable; second, in a low cash income and government planned economy at that time, these attributes were very limited and what was important to the rural consumers was not these attributes, but to get a bike in hand.

[27] It could be true that some single household might have 2 or more bikes in 1978 and a few following years, in which the household could have conspicuous satisfaction because of the bike. But the significance of the results in Section 4.4 supports the assumption of one attribute of bike. Because if this assumption does not hold, then the results cannot be significant. As least, in the following years, the attribute of conspicuousness of bike had been considerably decreasing because the household possession of bike had been increasing.

[28] Some bikers may carry more or less commercial goods with them on bikes.

[29] In Sections 4.2 and 4.3 we will construct a theoretical framework that the whole or most of expenditure on time saving goods has a special relationship with the households' total income, i.e., it will be a relatively stable share of the total income. Thus in this case study, we only set up the background here and after the explanation in Sections 4.2 and 4.3 we will take the rural households' expenditure on bike as a stable share of the total income. Indeed, the significance of the demand function will in turn confirm that this share is stable enough to make prediction. At least, from the significant results we can conclude that the share of bike over the total income is stable.

[30] At least no data show the daily bus operation in rural China before 1990s.

[31] Also no evidence shows that trucks were commonly used for daily passenger transportation in rural area before 1990s. Regarding tractors, first, they were not used for daily passenger transportation but used for agricultural production during that period; second, the general trend of tractors per 100 square kilometers of arable land had been decreasing in 1980s and early 1990s in China (World Bank, 2016) and the household possession of tractors was such low that there was no data to report it; third, usually the diesel, at least the diesel subsidy from the government, was controlled by the planned economy at that time. Thus tractors still could not be the daily passenger transportation in rural China before the middle of 1990s.

goods in rural China from 1978 through 1992, the data of such a real case could be applied in theoretical framework of Section 4.2 and the simple model built in Section 4.3 should have accurate prediction.

On the other hand, this dataset has a weak point. We have no data on how long of the time that a bike could save decades ago. Even we have no data on how long of the time that a bike had been used every day. Thus it seems the programming model cannot be operated without these data. However, after setting up the programming model, we find it is acceptable for lacking of the data because the saved time does not affect our purpose to obtain a demand function. We will elucidate it in light of time saving law in the following section.

4. 2 Time Saving Law

Besides the above data, we still need the household budget on purchasing bike. How to find this budget might be a special contribution of this paper. First of all, it is necessary to derive a law of budget share of time saving good, or a time saving law. Suppose a household has *n* identical laborers, each of them working t_0 hours per day, and the wage is *w* per hour per laborer. Then the total income per day of the household is equal to nwt_0. Further suppose a time saving good, e.g., a bike, can save t_1 hours of one laborer for the household.[32] If not considering the integer purchasing of the bike and the use of the bike for non-working purpose,[33] then the budget share *s* of the purchase on bike over the total income is

$$s \leq \frac{wt_1}{nwt_0 + wt_1} = \frac{t_1}{nt_0 + t_1} .$$

For the inequality of the formula, the denomination represents the new total income per day of the household, which include two parts. The first part is the original total income. Since after having the bike, all of the original work is finished within the time of t_0, for certain the household must get all of the original income. Suppose the household uses the saved time t_1 still to work at the wage *w*,[34] then the second part is its extra income, i.e., wt_1. Thus the new total income is the summation of the two parts. The numerator represents, since the extra income is wt_1, the household's maximum payment for the bike is also wt_1 per day. Therefore, the maximum value of the share *s* holds. After eliminating the wage *w*, the formula is simplified as the second equality.

Further, consider time saving as the fundamental human behavior, the household most probably will

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[32] Indeed, t_1 can also be considered as the saved time from not only the first bike, but from all the bikes the household possesses. Taking this definition in the formulas of this section will not change the final result.

[33] Because most of the households in rural China before the middle of 1990s were relatively low income households, they might not have noticeable budgets for non-working purposes, for example, buying a bike only for recreation. Moreover, the wage of the households in non-working time could be extremely low, thus the budget share or wiliness-to-pay for time saving good in non-working time also could be omitted.

[34] Although the working time had decreased from 70 hours to 41 hours per capita per week, or around 40%, from 1830 to 2002, it was a result that the income per capita had increased about 9 times during the same period(Greenwood and Vandenbroucke, 2005). Therefore, the decreasing of working time is a long-run process. In short-run, the assumption of fixed working time is reasonable when the income per capita does not increase significantly. The real changes of t_1 and the wage in extra working time may be complicated. But for simplicity, we assume they are not changed.

pay all the daily extra income wt_1 to maximize the objective of time saving if the time saving good has no integer constraint. Thus we can set an equality for the budget share:

$$s = \frac{wt_1}{nwt_0 + wt_1} = \frac{t_1}{nt_0 + t_1}.$$

But strictly speaking, most goods have more than one attributes, even some attributes are only a very tiny part of that good comparing to its primary attribute. If a household wants to purchase not only the primary attribute but other attributes, then its budget will be large than wt_1. Therefore, the actual budget share could also be larger than that in the above formula. Combing the two possibilities, it means in empirical research some average value of the budget share could be a better choice, especially when its explanatory and predictive powers are also better than other choices.

This formula may contain an interesting finding: the budget share of a time saving good has no relation with the wage or income of the household but is only determined by the saved time t_1, given n and t_0 are fixed.[35] Essentially, during a time period, the values of n and t_0 can be gathered in a survey and t_1 is the unique determinant of the share. Therefore, it could be defined as the time saving law.[36]

This law is the theoretical foundation to calibrate the programming model in one year, for annual data, and make prediction in other years. If n, t_0, and t_1 are stable in some years, then the share is also stable in these years. Therefore the calibration of the model in one of all the years can be the base year to predict the demand in other years. But the data in the formula is not always available and nothing guarantees whether the share is stable enough for making prediction. Thus the only method to handle this problem is to choose a suitable share as the calibration share and then solve the model in other years with such a calibration share. The suitable share could be a simple average of all annual shares.

The above method is only a hypothesis. It needs to be tested with the empirical data. In the next part of this section, we will examine the effectiveness of this method. Column 5 of table 1 reports the expenditure shares of bike in the rural households, which shows the share is between 4.97% and 7.44%, in 1982 and 1992 respectively. The share is calculated as the ratio of expenditure on bike, which is a product of the average unit price and the possession of bike, divided by the total income of 100 households. The simple average of all the annual shares is 6.19%.

The stability of this share depends on that of the extra saved time t_1. Without a survey, no conclusion can be drawn on whether t_1 is stable enough or not for the model. A reasonable logic, however, could

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[35] From this finding, a specific expression may be also interesting: since the share of time saving good does not determined by the income of the household, then hold other things equal and not consider the integer constraint, the income elasticity of demand of this good should be equal to one, i.e.,

$$e=1,$$

where e represents the income elasticity of demand for time saving good. We need empirical evidence to test this elasticity.

[36] It is easy to extend the law to more time saving goods. For the scope of the paper, however, it will not be discussed. But if we want to hold the share is stable, we have to consider all time saving goods.

be that if the results of the programming model based on this share that is determined by t_1 show the predictive power is significant, then we could not reject that t_1 is stable at least during that period.

There is another explanation of the stability of the share, i.e., the time period of the dataset in this paper is not long enough.[37] If we extend the time period of the dataset, that share may not be stable and the prediction may not be significant. However, we do not have more evidence to support this explanation, because the data of the price of bike after 1992 is unavailable. Thus, we could hold the assumption of the stable share before we have data to falsify it.

4.3 The Demand Function

Since the data is not sufficient for operating a programming model, the main purpose of this and next subsections is not to run such a model and obtain the solutions, but to find the demand function by the application of time saving law and then compare the accuracy of the predictive results of the programming model[38] with some most common econometric models.

In the programming model, because there is only one time saving good, i.e., the bike, then Model 1 can be reduced as

$$MaxT = t_{11} + t_{12} \qquad \text{[Model 2]}$$

$$\text{s.t.} \quad dp \le B$$

$$B = I \cdot s$$

$$t_{11}, t_{12} > 0$$

$$p, s > 0 ,$$

where T is the total time saved from using bike; t_{11} and t_{12} denote the time saved from using the first and second bike, respectively;[39] d is the demand of bike; p is the unit price of bike; B is budget on bike, which is a product of I, the household's income, and s, the household's budget share on bike; all variables are positive. Notice here, the integer constraint of the number of bike does not hold due to the data issue, thus d can be a decimal.

It is apparent that if the assumption of maximization of time saving holds, then the equals sign of model 2 in the first constraint will replace the inequality sign, i.e.,

$$dp = B .$$

[37] According to the fact that the household possession of bike in rural China had been decreasing since 1996 (National Bureau of Statistics of China, 2013), the time period of the dataset might be sufficiently long if we only consider the bike as the time saving good. After 1996, we have to consider bike and motorcycle together as the time saving goods. But the data of the price of motorcycle is unavailable.

[38] Due to data issue, we cannot run a programming model. But for simplicity of the whole paper, we still use this term.

[39] Because the total possession of bike per 100 households was less than 200, which means a household only had bikes less than 2 on average, thus we only need to consider 2 bikes here.

Further, if data of I, s and p are available, then the demand of bike d can be solved without knowing the time saved from the bike as

$$d = \frac{B}{p} = \frac{I \cdot s}{p}.$$

Therefore, we have the demand of bike in one year. Enumerate all of the annual data, we can derive the demand of bike in all years.

Columns 6 and 7 of Table 1 report the final results. Column 6 calculates the average budgets of 100 rural households on bike that is based on the simple average share s=6.19%, which is obtained in column 5. The demand of bike is in column 7 that is a quotient of the average budgets on bike over the price of bike.[40] We call this demand as "programming demand", which is also used in the first row of Table 2. When some functional forms are estimated based on this demand, we call them as "programming demand functions", which are in the following three rows of Table 2.

4.4 Comparison of Programming and Econometric Demand Functions

Regarding the accuracy of the programming demand, it is better to compare it with other demand functions. For the former, it is easy to run the demand and related determinants to obtain a function just as the third step discussed in Section 3.2. For the latter, the only formal method is to set up a utility maximization system or cost minimization system to derive a demand function. However, it seemed not easy to do that.

The most common method to find a demand function is to run an econometric model without any utility foundation. Based on the dataset, a group of the most common functional forms of the demand function is:

$$d_r = a_1 - a_2 p + u_1 \qquad \text{[Model 3]}$$

$$d_r = a_3 + a_4 i - a_5 p + u_2 \qquad \text{[Model 4]}$$

$$d_r = a_6 i - a_7 p + u_3 \qquad \text{[Model 5],}$$

[40] The utility theorists could argue that if the utility maximization is set as the objective function in Model 2, the same results of the demand function could also be obtained since the objective function is not involved in the operation of the model. But it is only correct for this argument in the economic explanation of the objective function. There is really no difference between the maximization of utility and maximization of time saving. However, the theoretical foundation of calculating the budget share of bike is entirely based on the new attribute theory and objective of time saving. Thus we have no reason to reject setting time saving as the objective function to keep the model compatible within itself. Further, since the objective function does not enter the solving of the model even if we set the objective function as utility maximization, thus the utility has totally nothing to do with the solution. This will not be a case to support the utility theory but to deny it. Because no evidence shows that the utility theory has a method that the utility function does not have to enter the operation of the model to find a demand function.

where d_r is the real demand of bike; a_1 ,…, a_7 are the coefficients; p is the price of bike; i is household's income;[41] u_1 , u_2 and u_3 are error terms.[42]

Correspondingly, the group of programming demand functions also takes the exact same forms. But the regressand is not the real demand in the column 1 of Table 1; it is the programming demand in the column 7 of Table 1. For conciseness of presentation, we omit the functional forms of the programming demand. The lower part in column 1 of Table 2 reports the results of the two groups of six demand functions, where d_p presents the programming demand of bike. We use Stata to estimate the econometric models.

Table 2. Comparison of Three Groups of Demand Functions

Methods	**Programming Demand and Demand Functions[a] (1)**	**Correlation Coefficient[b] of the Programming, Fitted Demand and the Real Demand (2)**	**R^2 of the Programming, Fitted Demand and the Real Demand (3)**
Programming Demand	The data is in column 7 of Table 1.	0.9583	0.9184
Programming Demand Functions	d_p=342.1872-1.9525p	0.9333	0.8712
	d_p=116.1662+0.00038i-0.7434p	0.9447	0.8925
	d_p=0.00055i-0.1010p	0.9267	0.8587
Econometric Demand Functions	d_r=411.2904-2.4493p	0.9333[c]	0.8712[c]
	d_r= 223.0057+0.00031i-1.4420p	0.9483	0.8992
	d_r=0.00065i-0.2089p	0.9294	0.8637(0.9801)[d]

Note: [a] All the t-tests are at least significant at the level of 10% and all F-tests are significant at the level of 1%, if applicable.
[b] The p-value of the correlation coefficient at significant level of 1% is 0.6411 (n-2=13).
[c] These two values are exactly equal to the second values in the same column, respectively.
[d] When an econometric function has no constant, its R^2 will not have a real value (Greene, 2012, p. 44-46; Gujarati and Porter, 2009, p.137). Stata reports it is 0.9801 but Microsoft Excel reports 0.8637.

Before we draw the findings from Table 2, it must be emphasized that both the results of correlation coefficient and R^2 are calculated between the programming demand (the data in column 7 of Table 1) or the fitted demand and the real demand (the data in column 1 of Table 1). For the group of last three rows of Table 2, this is not a problem, because the regressand in these three functions is the real

[41] Probably income should not directly enter the demand function as the time saving law implied. But just because it is a common practice that income usually is in a demand function, we take the functional forms with income.

[42] We do not consider the non-linear functional forms. The reasons are: first, linear functions are more common than non-linear ones; second, there is no evidence to support in this case that a non-linear demand function can be directly derived from a system of utility maximization. Because any demand function must be derived from a system of utility maximization or other optimization system. Therefore we only consider the linear functions.

demand. But for all other results, we need to know that no econometric software can automatically report the special R^2s. An easy way is using Microsoft Office Excel (hereinafter Excel) to calculate the results.

We consider Model 3 and Model 4 first. In Table 2, all the correlation coefficients are calculated by Excel. But the methods for finding some R^2s are not straightforward. For the programming demand, R^2 is computed between the programming demand and the real demand by Excel. The results are reported in the first row of Table 2, i.e., 0.9583 and 0.9184, respectively. For the group of programming demand functions, there are three steps to find the results. First, run two econometric models with the regressand of the programming demand and the regressors same as those in Model 3 and Model 4 by Stata. Second, calculate the fitted values of programming demand in these two models. Third, compute R^2s between the fitted values and the real demand by Excel. In this table, the results are 0.8712 and 0.8925, respectively. As a comparison, the group of econometric models of real demand is also reported in the table. A noticeable fact is that the two values of the correlation coefficient and R^2 for the first model, i.e., 0.9333 and 0.8712, respectively, are exactly equal to those for the corresponding model in the programming group.

Two findings can be drawn in Table 2. First, the two results that the correlation coefficient between the programming and real demand (0.9583) is higher than those of the group of econometric demand functions (0.9333 and 0.9483), which means that the programming demand has a significant relationship with the real demand as that of the econometric demand at 1% significant level, and the R^2 between the programming and real demand (0.9184) is higher than two of those of econometric demand functions (0.8712 and 0.8992), which means the former method can explain more variation of the real demand than the latter method, evidently prove that the predictive power of programming demand is at least as good as that of two most common econometric models.

The second finding is similar to the first one but is also important. From the result that the two correlation coefficients of the group of programming demand functions (0.9333 and 0.9447) are approximately equal to those of the group of econometric demand functions (0.9333 and 0.9483), we can conclude that comparing to the real demand, the programming demand functions are the highly related simulations as the econometric demand functions.

However, we can find there is another result that the two R^2s of the group of programming demand functions (0.8712 and 0.8925) are slightly lower than those of the group of econometric demand functions (0.8712 and 0.8992). Although this shows that one of the econometric demand functions, d_r= 223.0057+0.00031i-1.4420p, can explain the variation of real demand just a little bit higher than that of the programming demand functions, it should be noted that no any theory guarantees that this specific model is the best or correct demand function. Any demand function must be derived from a system of utility maximization[43] or other optimization system. But this model is not. The only reason that we take it as a demand function is it is one of the most common functions. Thus even its R^2 is higher than that of programming demand, it does not mean that the programming method is not a correct or good method to derive a demand function. Considering that there are no utility functions

[43] If it is not possible to set up a system of utility maximization and then derive a demand function based on the available data, then most probably the theory itself has some intrinsic defect.

behind these econometric demand functions, thus we could conclude that the attribute theory might be as good as utility theory.

If we have to consider Model 5 that has no constant in the demand function, we should pay attention to two issues. First, we need to know if included in the model, the *t*-test of the constant is significant or not. In Table 2, the constant of the econometric model (d_r= 223.0057+0.00031i-1.4420p) is at least significant at the level of 10%. Thus it is Model 4, not Model 5, that is appropriate to the data. Second, if it is necessary to consider Model 5, we need to recall that Greene (2012, p. 44-46) and Gujarati and Porter (2009, p. 137) have made it clear that the R^2 of a function without a constant may have no real value. That means in Table 2, the value of 0.9801 reported by Stata is not a real R^2. Comparing to the R^2 of programming demand function (0.8587), Excel reports the R^2 of 0.8637 for this econometric demand function.[44] Based on these two values, it is hard to conclude that the latter is significantly higher than the former. At the same time, it is also hard to conclude that the two correlation coefficients (0.9267 and 0.9294) have any significant difference because the only conclusion is they are all significant at the level of 1%. Moreover, both these two correlation coefficients and two R^2s are not higher than that of the programming demand, 0.9583 and 0.9184, respectively. Therefore, even it is necessary to consider the model without a constant, the results of this case further support the previous two findings that the predictive power of programming demand is as good as the econometric demand and the programming demand function is a good simulation as the econometric demand function.

It is worth noting that we set three assumptions before we obtain the final results. They are: the bike had only one primary attribute of time saving from 1978 through 1992 in rural China, the expenditure on bike was the largest part or even all of the whole expenditure on time saving goods, and the budget share on bike is stable. If any assumption does not hold, the final results cannot be significant. However, because the derived programming demand of bike is significant and the two findings of comparison among the three groups of demand functions are evident, we are able to confirm that the three assumptions hold.

5. Conclusions and Further Research

This paper builds the first programming model not with the objective of any utility but with that of time saving based on the new attribute theory. From this model, the demand function of the time saving good can be empirically derived by a programming method, which is a special non-parametric method. Although the data is unavailable to operate a complete programming model, this paper provides a case study and derives a demand function of bike with a simple method. The results show that both the programming demand and the programming demand functions are better than or at least as good as the most common econometric demand functions. The implication of the theoretical framework, including the new attribute theory and the objective of time saving, and the empirical evidence could be that it is worth attempting to switch foundation of Economics from the utility

[44] If the fitted values and residuals are orthogonal, which is a common assumption in linear regression, then R^2 equals the square of the related correlation coefficient in a linear function with a constant. Therefore, it is reasonable that the real R^2 in this function is 0.8637, because the square of the correlation coefficient is 0.92942 and then $0.9294^2 \approx 0.8638$.

theory with the objective of utility maximization to the new attribute theory with that of maximization of specific objectives.

In the sense of ultimate meaning, Economics probably just indicates time saving. If Economics takes the specific objective of time saving as one of the operational starting points, it will be a science of real world. Utility theory might not be a perfect theory, which heavily depends on a serial of strict assumptions, and set Economics on the shifting sands. The new attribute theory can directly solve the optimizing models based on discrete preferences and should be a more general theory than the utility theory and could be an alternative theory as the foundation of Economics. If combining the new attribute theory and the starting point of time saving, Economics will be built on a solid rock.

The classical economic thoughts of time saving can be generalized to some fundamental theories of Economics, in particular the long-run growth theory. Most probably, the objective of long-run growth is just to save time by institutional change, including the division of labor and reciprocal trade, and technical progress. After we create economic growth in the time saving industries, such as agriculture and manufacture industries, which means we produce the same goods with less time, then we are able to develop the time-consuming industries, such as arts and tourism industries. Moreover, business cycle could be a consequence of the changes of the two industries. Therefore, time saving might be a milestone that will shift Economics from the new classical and neo-classical era to a modern era.

References:

Aguiar, M., E. Hurst, and L. Karabarbounis. 2012. "Recent developments in the economics of time use." *Annual Review of Economics.* 102(4), 373-397.

Becker, Gary S. 1965. "A theory of the allocation of time." *The Economic Journal*, 75 (299): 493-517.

Lester Brown. 2011. "The Planet's Scarcest Resource Is Time." www.thenation.com/article/lester-brown-planets-scarcest-resource-time/

Dardi, Marco. 2008. "Utilitarianism without Utility: A Missed Opportunity in Alfred Marshall's Theory of Market Choice." *History of Political Economy*. 40(4):613-632.

Dominique, C-Rene, "Should the Utility Function Be Ditched?" Munich Personal RePEc Archive paper 5987, University Library of Munich, Germany, 2007.

Dominique, C-Rene, 2008. "Walrasian Solutions without Utility Functions." Munich Personal RePEc Archive paper 8906, University Library of Munich, Germany, revised 2008.

Dorfman, Robert，Paul A. Samuelson, and Robert M. Solow. 1987. *Linear Programming and Economic Analysis*. p. 3. New York: Dover Publications.

Greene, William H. 2012. *Econometric Analysis*. 7th ed. p. 44-46. Upper Saddle River: Prentice Hall.

Greenwood, Jeremy, and Guillaume Vandenbroucke，2005. "Hours Worked: Long-run Trends", NBER Working Paper 11629.

Gujarati, Damodar N., and Dawn Porter. 2009. *Basic Econometrics*. 5th ed. p. 137. New York: The McGraw-Hill Companies, Inc.

Heckman, James. 2014. "Introduction to a Theory of the Allocation of Time by Gary Becker." Discussion Paper No. 8424. The Institute for the Study of Labor (IZA).

Jehle, Geoffrey A., and Philip J. Reny. 2011. *Advanced Microeconomic Theory*. 3rd ed. p. 24. Harlow:Pearson

Education.
Kennedy, Eileen, and Thomas Reardon. 1994. “Shift to Non-traditional Grains in the Diets of East and West Africa: Role of Women's Opportunity Cost of Time.” *Food Policy*. 19(1): 45-56.
Krugman, Paul, and Robin Wells. *Microeconomics*. 2012. 3rd ed. p. 6. New York: Worth Publishers.
Lancaster, Kelvin. J. 1966. “A New Approach to Consumer Theory.” *Journal of Political Economy* 74(2): 132-157.
Mankiw, N. Gregory. 2015. *Principles of Microeconomics*. 7th ed. p. 4. Toronto: Nelson Education.
Mas-Colell, Andreu, Michael D. Whinston, and Jerry R. Green. 1995. *Microeconomic Theory*. p. 47. New York: Oxford University Presss.
Marx, Karl. *Grundrisse, Foundation of the Critique of Political Economy*. 1857-61. Penguin Books in association with New Left Review, 1973. p. 173. Online edition: https://www.marxists.org/archive/marx/works/1857/grundrisse/ch03.htm
McCarl, Bruce A. and Thomas H. Spreen. 2004. *Applied Mathematical Programming Using Algebraic Systems.* College Station, TX: Texas A&M University.
McCracken, Vicki A., and Jon A. Brand. 1990. “Time Value and Its Impact on Household Food Expenditures Away From Home.” *Home Economics Research Journal*. 18(4): 267-285.
McGuire, Judith, and Barry M Popkin. 1990. “Beating the Zero Sum Game: Women and Nutrition in the Third World.” In *Women and Nutrition - Nutrition Policy Discussion Paper* No. 6. Administrative Committee on Coordination/Subcommittee on Nutrition Symposium Report. United Nations. http://www.unsystem.org/SCN/archives/npp06/begin.htm#Contents
Mises, Ludwig Von, 1951. *Socialism: An Economic and Sociological Analysis*. Reprinted, 1962. pp. 164-165. New Heaven: Yale University Press.
National Bureau of Statistics of China. 2004. Women and Men in China: Facts and Figures. pp. 100-106. http://www.stats.gov.cn/english/statisticaldata/otherdata/men&women_en.pdf.
National Bureau of Statistics of China. 1999. *Comprehensive Statistical Data and Materials on 50 Years of New China*. Table A-22. Beijing: China Statistics Press.
National Bureau of Statistics of China. 1979-1993, 2013. *China Statistical Yearbook*. Beijing: China Statistics Press.
Paris, Q., 1991. *An Economic Interpretation of Linear Programming.* Ames, Iowa: Iowa State University Press.
Samuelson, Paul A., and William D. Nordhaus. 2010. *Economics*. 19th (Special Indian) ed. p. 4. New York: The Tata McGraw-Hill.
Senauer, Ben, David Sahn, and Harold Alderman. 1986. “The Effect of the Value of Time on Food Consumption Patterns in Developing Countries: Evidence from Sri Lanka.” *American Journal of Agricultural Economics*. 68(4): 920-927.
Sinha, Chris, Vera da Silva Sinha, Jörg Zinken, and Wany Sampaio. 2011. “When Time is not Space: The social and linguistic construction of time intervals and temporal event relations in an Amazonian culture.” *Language and Cognition,* 3(1): 137-169.
Smith, Adam. 1776. *An Inquiry into the Nature and Cause of the Wealth of Nations*. 5th ed. London: Methuen & Co. 1904. p. 17. Online edition: http://www.econlib.org/library/Smith/smWN1.html#B.I, Ch.1, Of the Division of Labor.
Stigler, George J. 1950. “The Development of Utility Theory (I, II).” *Journal of Political Economy* 58(4): 307-327; 58(5): 373-396.

World Bank, 2016. The Figure of Agricultural machinery, tractors per 100 sq. km of arable land. http://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&strail=false&bcs=d&nselm=h&met_y=ag_lnd_trac_zs&scale_y=lin&ind_y=false&rdim=region&idim=country:CHN&ifdim=region&hl=en_US&dl=en_US&ind=false

Zhu, D, 2011, "Demand Curve without Utility Function." Department Annual Conference (January 2011), Department of Resource Economics and Environmental Sociology, University of Alberta.

Appendix:

To find the real price of bike, we need adjust the normal price of bike by a price index. In Table A1, although the rural residents' consumer price index by category in column 2 may be a suitable index, it has no data before 1985. For the other two indices in column 3 and 4, the correlation coefficient between them is 0.9903, while the *p*-value at significant level of 1% is 0.6411 (n-2=13). First, it means that it is almost no difference to use one of them to adjust the price of bike. Second, if the rural price index is more appropriate for the adjustment but we use the urban one, and if the results significantly support our conclusions, then our conclusions will not be weakened but strengthened. Therefore in this paper, the urban residents' consumer price index in column 4 is used to adjust the normal price to real price of bike.

Table A1. The Comparable Price of Bike in Rural China: 1978-1992

Year	Normal Price (Chinese *yuan*) (1)	Rural Residents' Consumer Price Index by Category (preceding year=100) (2)	Overall Industrial Products Rural Retail Price Index (1978=100) (3)	Urban Residents' Consumer Price Index (1978=100) (4)	Comparable Price (Chinese *yuan*) (5)=(1)*(4)
1978	159.00	-	100.00	100.00	159.00
1979	159.00	-	100.10	101.90	156.04
1980	161.00	-	100.90	109.50	147.03
1981	164.00	-	101.90	112.20	146.17
1982	163.00	-	103.50	114.40	142.48
1983	164.00	-	104.50	116.70	140.53
1984	164.00	-	107.70	119.90	136.78
1985	168.20	100.00	111.10	134.20	125.34
1986	185.80	106.10	114.70	143.60	129.39
1987	213.40	112.70	120.20	156.20	136.62
1988	239.40	132.40	138.50	188.50	127.00
1989	271.00	157.90	164.40	219.20	123.63
1990	260.00	165.10	172.00	222.00	117.12
1991	280.20	168.90	177.20	233.30	120.10
1992	314.90	176.80	182.70	253.40	124.27

Source: National Bureau of Statistics of China, 1993.

Table A2 reports the results of net income of 100 rural households in China. Based on the net income index in column 1 and the first income in 1978, we are able to compute the net income per capita of rural household, which is in column 2. Further, the net income per rural household is a product of column 2 and the average permanent residents per rural household in column 3. Therefore, the final results are a product of column 4 and 100.

Table A2. The Net Income of 100 Rural Households in China: 1978-1992

Year	Net Income Index (1978=100) (1)	Net Income per Capita of Rural Household (Chinese *yuan*) (2)=(1)*133.60/100	Average Permanent Residents per Rural Household (Person) (3)	Net Income per Rural Household (Chinese *yuan*) (4)=(2)*(3)	Net Income of 100 Rural Households (Chinese *yuan*) (5)=(4)*100
1978	100.00	133.60	5.74	766.86	76686.40
1979	120.00[a]	160.32	5.66	907.41	90741.12
1980	139.00	185.70	5.54	1028.80	102880.02
1981	167.30	223.51	5.50	1229.32	122932.04
1982	202.20	270.14	5.46	1474.96	147496.00
1983	231.90	309.82	5.43	1682.31	168231.39
1984	265.00	354.04	5.37	1901.19	190119.48
1985	268.90	359.25	5.12	1839.36	183936.20
1986	277.60	370.87	5.07	1880.33	188032.92
1987	292.00	390.11	5.01	1954.46	195446.11
1988	310.70	415.10	4.94	2050.57	205057.03
1989	305.70	408.42	4.86	1984.90	198489.79
1990	311.20	415.76	4.80	1995.66	199566.34
1991	317.40	424.05	4.71	1997.26	199725.85
1992	336.20	449.16	4.67	2097.59	209759.21

Note: [a]Datum of 1979 is an average of those of 1978 and 1980.

Source: National Bureau of Statistics of China, 1999.