

Extending the Household Sector of MacroLab to  
Improve the Explanation of Trend in Personal Saving  
Rate in the U.S.

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## **Abstract**

*MacroLab (Wheat 2007 a) is a system dynamics model of the U.S. economy. It was developed to improve understanding of macroeconomics. In particular, it helps students to learn about the dynamics of an economy.*

*This study takes a new look at the concept of consumption and saving behavior in private sector, and evaluates the household sector of MacroLab.*

*The present paper seeks to extend the household sector of MacroLab by adding the effect of price level on people's consumption and saving behavior based on categorizing their consumption to "Essential" and "Discretionary".*

*The extended model generates more accurate consumption and saving behavior than the outcome of household sector of MacroLab compared to the historical data.*

**Key words:** *System Dynamics, MacroLab, Household Consumption and Saving, Disposable Income, interest rate, price level and tax rate, economics education*

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# Introduction

## 1.1 Preface

One important concept in system dynamics models as pedagogical tool is the idea of mental models. People have in their minds mental representations of their life, families, cities.... These mental models that we create of our world around us can be very bright and detailed. However, those models are often inaccurate and frequently change. So that, by using computer models we can use people's mental models to understand about their decision-making and let the computer trace through the system from causes to effects.

MacroLab (ML) is a system dynamics model of the U.S. economy. It seeks to improve learning of macroeconomics by a different way of presenting economic structure and behavior. What differentiates MacroLab from other methods to teach macroeconomics is how the story of economic structure and behavior is demonstrated. The first distinction is the emphasis on dynamics rather than static conditions. Changes in the economy over time and in different situations is the behavioral question that students frequently come across and they can see the answers with simulating time series graph with both historical styles and simulated behavior . In addition, a detail of the structure of the economy is given in a language of reinforcing and balancing feedback loops. "Students are encouraged to "think in time" and envision patterns that unfold and interact in reinforcing or counteracting ways with earlier trends, instead of focusing on isolated cause-and-effect events" (Wheat 2007 a).

Interact method of ML creates more engagement in construction of the model and test driving the simulator. "MacroLab consists of about 300 U.S. sector equations, plus about 200 more for the foreign sector"(Wheat 2007 b).

Wheat noted that "MacroLab provides students with a different conceptual lens through which to view the structure and behavior of the economy"(Wheat 2007 a). Working with ML model helps students understand how and why the U.S. economy behaves based on the structure. The household sector of ML, which includes consumption and saving, is the focus in this study.

The household sector of ML relies on disposable income and interest rate to determine consumption and saving. However, this research is undertaken to extend that sector of ML by adding prices and also by distinguishing between essential and discretionary consumption.

The results of the new model are encouraging, as it creates more realistic behavior of saving rate compared to historical data (NIPA based data) which will be explained later in this paper.

The extended model can replace with the old version of the household sector of MacroLab.

## **1.2 Data and Research Method**

The data which are used in this study, are mostly taken from BEA which is the U.S. Bureau of Economic Analysis in the department of Commerce (Bureau of Economic Analysis 2011) especially NIPA tables for collecting income and its dispositions and personal tax and outlays. In some cases the data are taken from the US Census Bureau (Bureau 2011) for collecting the yearly poverty threshold values and World International Bank (The World Bank 2011) for total population.

Wall Street journal website (FedPrimeRate.com 2011) was very useful to collect reliable data for the prime rate in the U.S.

System Dynamics (SD) is used as the research method for this study. SD is a method for learning complex systems. Thus its application can improve our understanding of the dynamics and the complexity of different systems with different concepts such as: economic, business, health, politic etc. The SD method has been tested in individual researches in order to promote and simplify the learning of feedback and delay in systems as well as their misperceptions (Sterman 2000), (Moxnes and Krakenes 2004) and (Wheat 2007 a). The concept of SD is defined by the structure of stocks and flows in a model which is well illustrated by John Sterman (Sterman 2000).

The data were obtained and the model is built by using system dynamics (SD) simulation software called **iThink**, which is used by Wheat to develop ML as well. iThink is a product of **isee system** (<http://www.iseesystems.com>).

## **1.3 Literature Review**

### **1.3.1 Computer Simulations as Learning Tools**

MacroLab was motivated, in part, by documenting weakness in traditional economy education.

Traditional typical academic economics as a science were unsuccessful to illustrate real life economic behavior (Forrester 2003). Cohen (Cohn et al. 2001) conducted some experiments and it is found that traditional explanation for the graphical procedure to economic dynamics has no effect on student's ability to learn macroeconomics. Bartlett and King (Bartlett and King 1990) claimed that teaching economics have remained unchanged over the last years. They traced advances in transforming the traditional formats for teaching economics to laboratory science tools (computer tools), which can help students in the learning process. Grimes and Willey (Grimes and Willey 1990) experimented the effectiveness of teaching a computer simulation based program in the traditional principles of economics course between two groups of students at Mississippi State University. They accomplished that computerized simulations can be an efficient instructional tool in the principles of economics path.

MacroLab includes interactive learning environments (ILE) for macroeconomics. Wheat also conducted experiment on ML, which was built on a traditional economy modeling with SD tool. He comes to the conclusion that students, who used MacroLab simulator, gain better economic understanding by using the ILE of ML (Wheat 2007 b).

### **1.3.2 The Household behavior**

The household sector of the U.S. is a sub model of MacroLab. That sector simulates household spending and saving based on propensity to consume of disposable income. In ML, interest rate is responsible for decreasing or increasing in propensity to consume.

In reality, other factors can affect the household behavior rather than only interest rate. There is a vast amount of literature on the effect of different parameters on household's consumption and saving behavior. Radzicki, Pavlov and Nicholas (Radzicki, Pavlov, and

Nicholas 2006) highlight that inflation has a significant impact on income shares. Since inflation is changes in the general level of prices, it is important to assess people's income with respect to inflation in order to show income shares under different prices.

Attanasio and Paiella (Attanasio and Paiella 2002) are also mentioned that it is important to have a deep insight into the dynamics of household behavior with considering the relationship between inflation, income and consumption.

One common model of consumer behavior in the economy is the lifecycle model which was originally introduced in 1954 by Modigliani and Brumberg. That model assumes that people adjust their consumption and saving at various times in their lives by considering their future income, rather than assuming only their current income and propensity to spend (Modigliani and Brumberg 1954), Ando and Modigliani (Ando and Modigliani 1963). Following, lots of literatures on the theory of the consumption function, with debates of the permanent income hypothesis, developed a proposition of the impact of life cycle (aging) on consumer expenditure (income and consumption).

Later Axel B Supan (Supan 2003) wrote about life cycle saving in six countries included the U.S. (Elmendorf 1996). Elmendorf also analyzed that people's life style and the effect of life cycle (different ages) on making decisions about balancing between consumption and savings. It has to be pointed that, the household sector of ML and the model of this study do not incorporate the lifecycle influence.

Furthermore, a framework of tax treatment of saving as the heart of the lifecycle hypothesis of Modigliani and Brumberg traced by Bernheim (Bernheim 2002). He also examined empirical proof on the saving effects of various tax policies. Attanasio (Attanasio 1994) studied that how tax incentives have a considerable effect on household's consumption and saving behavior in the United States. It must be emphasized that, the new model and the household sector of ML both include the effect of taxes via disposable income.

In 1996 Elmendorf (Elmendorf 1996) concentrated on the effect of interest rates on household saving and consumption. He mentioned that changes in interest rate can encourage or discourage people to consume more or less and makes decrease or increase in saving. The new household sector and ML both include exactly the same interest rate effect based on Colin Wight research (Wright 1969).

One of the other aspects of household consumption behavior is analyzing consumption based on people's necessities. It puts people's essential needs versus their discretionary (non

essential) needs. The U.S. department of Labor Statistics (U.S. Department of Labor 2006) published a report on 100 Years of U.S. Consumer Spending. They defined that food, shelter and clothing are necessity for people's life and counted them as essential and the rest of people's consumption is what they spend on discretionary items. As well as that, the report concludes how much (in dollars) households spent on both essential and discretionary in past 100 years in the U.S.

Fatas and Villafranca In 2009 (Fatás-Villafranca, Saura, and Vazquez 2009) analyzed the dynamic of discretionary consumption. They reported that in economics and sociology, consumption activities that are not necessary for life, which are called discretionary consumption activities, have the characteristic of helping people to integrate their personal and social identities. They concluded that one of the best research strategies about the dynamic of consumption is by defining the correct explanation of discretionary (and as a result essential) consumption.

In this study the effect of inflation (prices) and interest rate on propensity to consume with respect to essential and discretionary perceptions, and the effect of tax rate on income are focused. It should be observed that the model of this study takes the effect of interest rate from the household sector of ML and then the model is extended by adding the effect of inflation (prices) and changing the characteristic of consumption by dividing to two observations as essential and discretionary. Effect of tax rate is considered in ML and the new model by inserting the disposable income into the models.

#### **1.4 Research Objective and Question:**

The objective of this study is to increase the realism of household sector behavior of MacroLab by adding the effect of prices (inflation) and categorizing consumption to essential and discretionary.

The research question for this study is how the presenting behavior of the household sector of ML compared to real life can improve, while preserving the simplicity necessary for ML educational purpose.

This paper is divided into five sections. The first section gives a brief overview of the main statement of the research problem. It also gives a general background of MacroLab. The

second section discusses the definition of the problem. Section three presents the hypothesis and the structure of the model in this study.

In fourth section analyses are presented and it is shown that how system's behavior is analyzed. A comparison between previous and current consumption sectors is described in this section as well. Conclusions, limitations, discussions and some recommendations are drawn in the final (fifth) section.

This study is not aim to build the US macro model which is required to show how the whole economy functions interact with each other. So a discussion of how other economic variables can affect each other fall outside the scope of this study.

## **2. Background of Issue**

### **2.1 A History of American Household Behaviors**

As it is explained in previous section, the main goal of this study is focused on improving the household sector of ML which was designed as a tool to give instructions to students, who want to learn macroeconomics. In order to define how it is possible to present a better understanding of household behavior of ML, it is necessary to review a history of household behavior in the US and its distinctions.

In recent decades consumers live in a social formation that encourages them to spend more money by offering many new financial advances. Those innovations in financing consumption merged with historically conditions, such as declining in interest rates and significantly extended the access to credit for American households led to higher consumption level in the U.S. (Cynamon and Fazzari 2010).

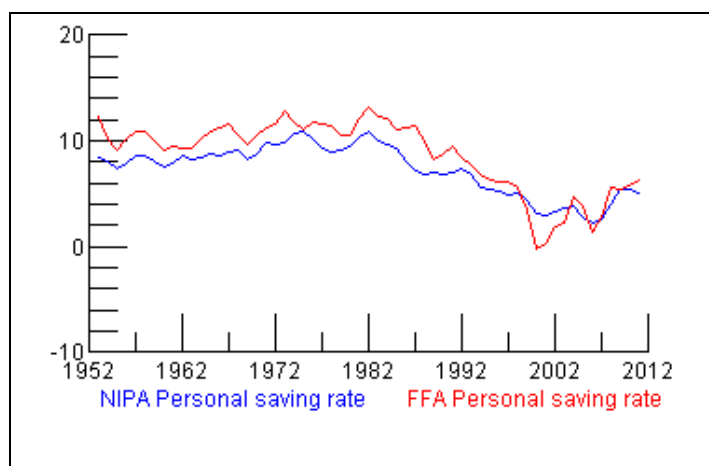
In the literature, saving is a residual and it usually refers to what is left from personal income after deducting consumption and taxes or after deducting from aggregate income consumption by households and government. In this context, economic theories seek to explain people's preferences in relation to consumption and saving over the course of their life (Radzicki 1988).

Figure 1 shows saving behavior in the U.S. measured as a percentage of disposable income which is called “saving rate”.

Decreasing in household’s saving rate in the U.S. during previous years becomes a critical issue and it shows there is need to investigate more about household’s behavior and to identify parameters which determine people’s consumption-saving priorities. This sector is distinguished because the importance of saving for increasing the capacity to produce goods and services. Researchers have always seen consumption as productive resources in the present, while saving elaborate the resources available for production and consumption in the future (Tobin 2012).

Personal saving rate in the U.S. is calculated by two different sources: the National Income and Product Accounts (NIPA) estimates from the Bureau of Economic Analysis (BEA) and the Flow of Funds Accounts (FFA) from the Board of Governors of the Federal

Reserve System (BOG). Although, they rely on slightly different measures, but their trends are very similar. The data from NIPA is used as a reference mode in this study.



Source: Bureau of Economic Analysis (The US Department of Commerce)

Figure 1: The US personal saving rate 1980 - 2011

## 2.2 Definition of Problem

Figure 2 shows **there is a difference between the behavior of household sector of MacroLab and the NIPA- based reality as historical saving rate.**

The household sector of ML has only focused on propensity to consume from disposable income, where propensity to consume is influenced by changes in interest rate. This study takes a look at household consumption and saving behavior with examining the influence of propensity to consume with the goal of improving the “fit” between ML household sector saving rate and the historical trend in saving rate.

As a consequence, the problematic dynamic behavior is the discrepancy between ML’s saving rate and NIPA’s saving rate data (Figure 2).



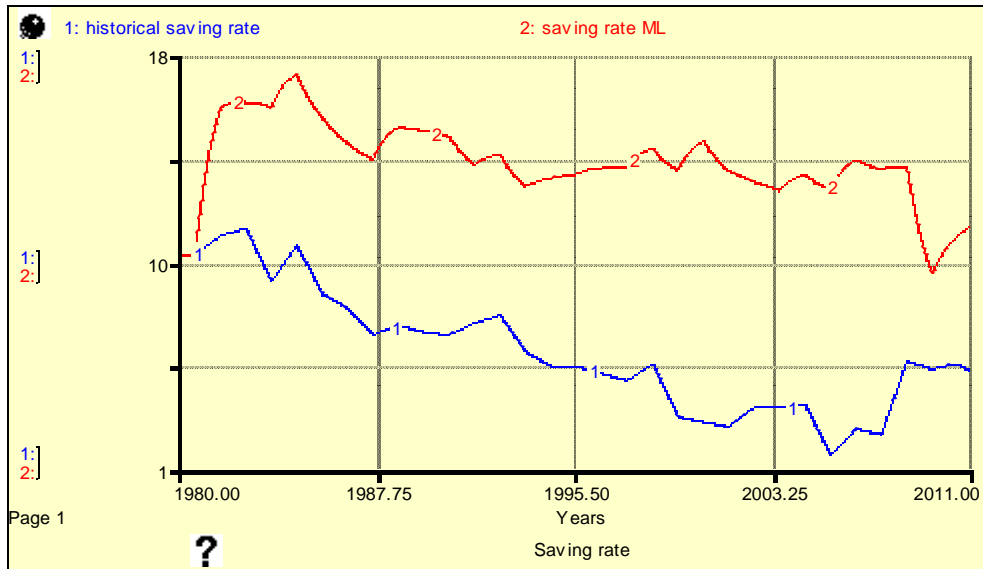


Figure 2: Comparison of saving rate behavior of ML and historical saving rate

### 3. Description of Hypothesis and Model

#### 3.1 Description of Hypothesis

This study is seeking to address “Why MacroLab household sector creates such a behavior in Figure 2 and if it is possible to improve it by adding other parameters in order to produce a better behavior”.

So the hypothesis of this study is: **An extended version of household sector of ML that adds the effect of prices (inflation) on consumption and distinguishes between essential and discretionary consumption can create better behavior.**

It was decided that the best procedure for this study is to detach the household sector from ML and consider it as a stand-alone model. So having an independent sector of ML means that we are able to build a new model by considering other factors of the US economy exogenously, feed both models with the same input data and compare the results.

In MacroLab, outputs of the household sector affect the rest of the model and it also receives some inputs from the rest of the model. So the first step is disconnecting the household sector from ML. Figure 3 shows how household sector and the rest of ML interact with each other.

In order to evaluate the hypothesis, a partial model testing is conducted and personal saving rate reference mode (Figure 1) validation as one of the most important outputs of this sector is used.

Partial model testing is a technique to analyze the behavior of individual part (or parts) of a model by taking exogenous input data (e.g., disposable income) and see which formulation or selection of parameter values are reasonable to contribute sufficient fit to historical data. It is noticeable that equations and parameter values should be persuasively based on real life even for those which have uncertain estimations (Homer 1983).

Testing procedure partial model validation for this study is done by using exogenous historical data for disposable income and interest rate to improve the behavior of saving rate compare to NIPA’s data. In this model, the parameters are adjustment times and the slope of nonlinear function that represents the effect of inflation on discretionary propensity to consume.

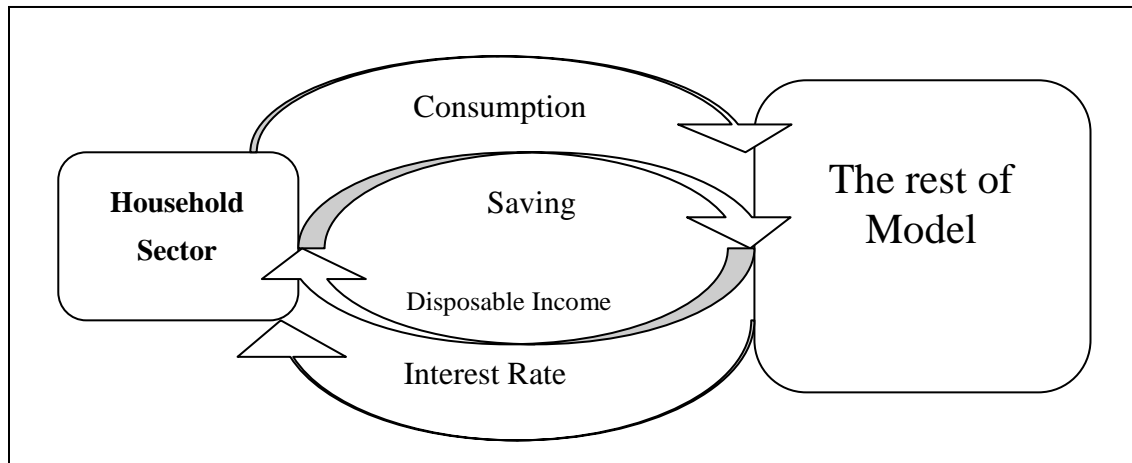


Figure 3: Interaction between household sector and the rest of ML.

## 3.2 Description of Model

### 3.2.1 Overview of the MacroLab Model Structure

Traditional version of ML includes different sub models as: production, income distribution, consumption, government, banking, and foreign sectors. However, ML has been updated many times and as a consequence, sub model names has been revised as well. “**Consumption**” sector of ML is updated to “**Household**” sector which is chosen to use in this study.

In order to understand the structure of ML and the role of consumption-saving variables, a very simple macro model in Figure 4 shows the relation between households, government and business sectors in the real world.

The graph demonstrates a very simplified version of the structure of the main model, and for the reason of simplicity, the diagram shows only those information links that connect

the model's real part (bottom) with its nominal part (top), which are also indicated as the "supply side" and "demand side," correspondingly.

Nominal values stream through the demand sector, whereas the real values stream through the supply side. Part of nominal income, which is accomplished by the supply side, is allocated between households, government, and businesses on the demand side of diagram.

From the right side, the nominal aggregate demand, which is the amount of spending by households, government, and businesses, plus net exports, from demand side is transformed to real aggregate demand on the supply side.

Stocks of labor and capital are determined by the production sub model. Household spending ("consumption"), which is a considerable part of disposable income, is determined by the household sub model. Then personal saving (as a flow) and savings (as stock) can be defined based on consumption. Capital accomplishment determination from production sub model conditions investment spending although it is financed by stock of savings.

Taxes flow through the government sub model and when government has deficit (spends more than purchasing taxes) in its budget, government saving rate is negative and it is fed by the stock of saving to reduce the amount of deficit. In addition, government debt, and interest payments are incorporated from the government sub model.

The banking sub model determines interest rate which is an input for both the household sub model and the production sub model. The banking sub model provides monetary flows between stocks of bank deposits and money, which is kept by people in addition to those flows and from bank reserves.

The foreign sub model, which is called the "rest of the world" by Wheat in his documentation of ML, is a clone of the domestic main model and all of its sub models. It facilitates display of some interactive consequences between two economies (on demand side and supply side) for purpose of macroeconomics instruction.

All above explanations of Figure 4 is provided from the documentation on traditional version of MacroLab which was written by Wheat in 2007.(Wheat 2007 a)

Updated to Household sector

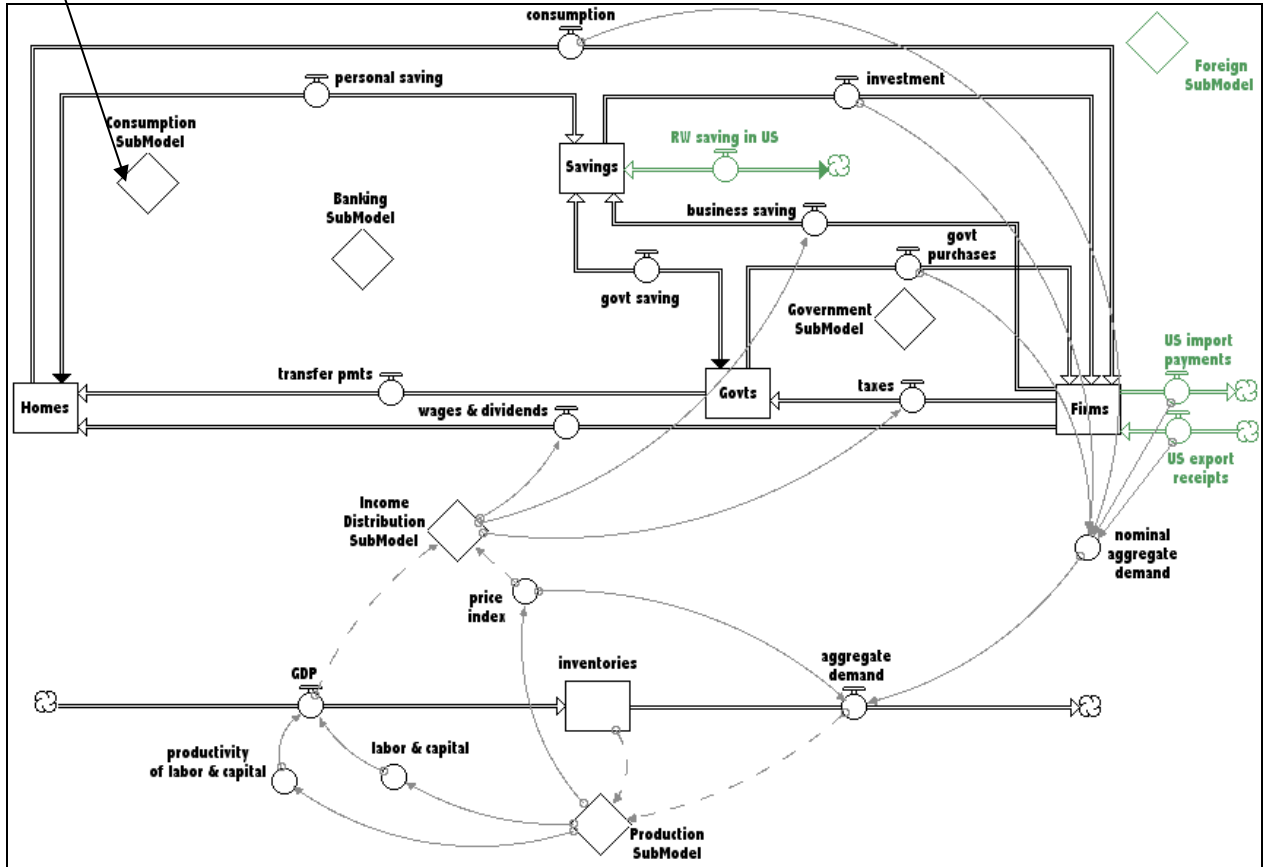


Figure 4: High level overview of traditional version of MacroLab  
 Source: MacroLab documentation(Wheat 2007 a)

**NOTES:**

\* The diagram does not show all feedback loops. It shows just the main reinforcing loop that connects supply side to demand side.

### 3.2.2 Causal Loop Diagram of MacroLab

The feedback loop diagram (causal loop diagram) of MacroLab (Figure 5) demonstrates how the model's structure generates changes in stocks.

First, if personal saving grows, capital investment and stock of savings grow and then it gives a push to firms which provide a rise in both business saving and household disposable income. However, interest rate has a negative impact on investment and saving has a negative effect on interest rates. It means that if savings go up interest rates decrease (Loop R1) and more investment causes less money in savings accounts then loop B1 is created.

Income is the most relevant determinant of consumption and personal saving. So any increase in income leads the structure in a way to increase the consumption. Interest rates also have a negative effect on consumption in ML. The growth in consumption (part of aggregate demand) encourages firms to produce more. More production (GDP) increases income, which increases consumption in loop R2.

In addition, there is another reinforcing loop (R3) which shows any increasing in aggregate demand (AD) can indicate to invest more and more investment means more growth in aggregate demand. The second effect of consumption growth (as part of AD) and aggregate demand is increasing in taxes, which decreases income in loop B2.

When price enters into the model, aggregate demand is affected immediately. Rising in prices can cause reduction in AD and inventories where loop B3 creates this activity.

As well as that, Investment is determining capital. Loop R4 illustrates how government receives taxes and by increasing in government purchases, AD increases.

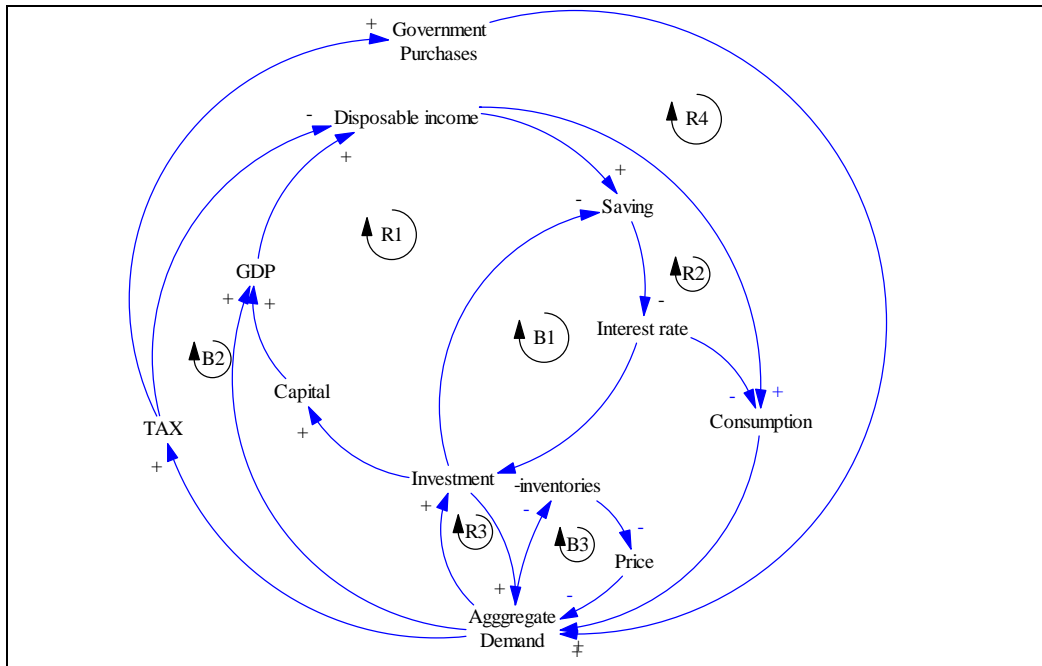


Figure 5: Simplified Causal Loop Diagram of MacroLab

Therefore, capital investment, consumption and business saving which have positive effects on AD should be considered in order to observe AD (aggregate demand). In addition, AD affects GDP, national income and household disposable income. So each decrease or increase in AD can conduct the whole structure to react.

### 3.2.3 Overview of MacroLab Household Sector and its equations:

Figure 6 shows the household sub model of ML and its location.

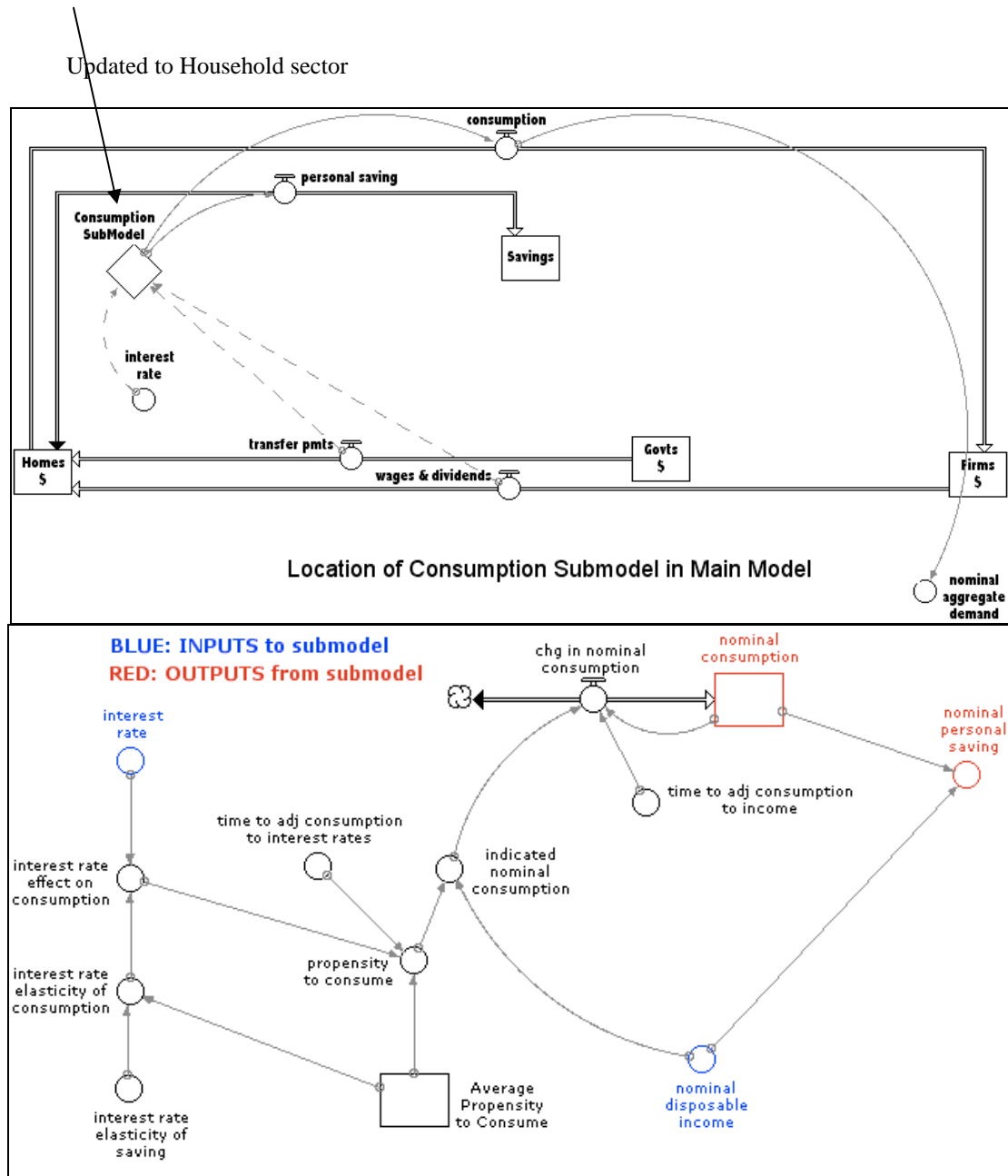


Figure 6: Household sector of MacroLab.  
 Source: MacroLab documentation(Wheat 2007 a)

As it is illustrated in Figure 6 (the overview of consumption structure of ML in detail), the inputs to the consumption sub model are disposable income and interest rate. Those variables are determined endogenously in ML, but in the model of this study they are treated exogenously by using historical data.



So that it is possible to compare both versions' outputs with the same input. Table 1 indicates all equations and variable assumptions of household sub model in the original ML (Wheat 2007 a).


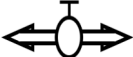









		Left Side of Equation	Right Side of Equation
1		nominal consumption(t)	nominal consumption(t - dt) + (chgs in nominal consumption) * dt INIT historical= historic real C INIT experimental = indicated nominal consumption
2		chgs in nominal consumption	(indicated nominal consumption - nominal consumption) / consumption adj time
3		indicated nominal consumption	disposable income * propensity to consume
4		time to adjust consumption to income	2.5 year
5		propensity to consume	average propensity to consume * smth l (interest rate effect on consumption ,time to adjust consumption to interest rates)
6		average propensity to consume(t)	average Propensity to Consume(t - dt) INIT experimental = (wages & dividends+business saving + taxes -investment -govt purchases) / (disposable income)
7		interest rate effect on consumption	1+((interest rate - init(interest rate)) / init(interest rate) *interest rate elasticity of consumption)
8		interest rate elasticity of consumption	-interest elasticity of saving / (average propensity to consume / (1- average propensity to consume))
9		interest rate elasticity of saving	0,2
10		time to adjust consumption to interest rates	0.5 year
11		nominal personal saving	disposable income - nominal consumption

Table 1: Household Sector equations of MacroLab

Source: MacroLab Documentation(Wheat 2007 a)

In Figure 6, interest rate has a negative effect on consumption. An increase in interest rate makes less consumption and more savings and opposite of that decreasing in interest rate makes more consumption and less saving. So the equation (Table 1-equation 8) which represents that effect is:

$$\text{Interest rate elasticity of consumption} = -\text{interest elasticity of saving} / ((\text{Reference propensity to consume}) / (1 - \text{Reference propensity to consume}))$$

The model will be on average equilibrium when **interest elasticity of saving = 0.2** and **Reference propensity to consume = 0.9**.

So as a result the key variable for consumption in this sub model is interest rate and propensity to consume and as a consequence changes in consumption are evaluated based on interest rate. Then we have (Table 1-equation 7):

$$\text{Interest rate effect on consumption} = 1 + ((\text{Money supply interest rate} - \text{init (Money supply interest rate)}) / \text{init (Money supply interest rate)}) * \text{interest rate elasticity of consumption}$$

Money supply interest rate is an input from money supply sector of ML. Below equation reveals how propensity to consume (Table 1-equation 5) is calculated:

$$\text{Propensity to consume} = \text{smth1 (interest rate effect on consumption, time to adjust consumption to interest rates)}$$

and adjustment time for this equation is equal to **0.25 (3 months)**

On combining that result with disposable income, which is an input from income sector of ML, indicated nominal consumption (Table 1-equation 2 and 3) and change in nominal consumption are:

$$\text{Indicated nominal consumption} = \text{Disposable income ML} * \text{propensity to consume}$$

$$\text{Change in nominal consumption} = (\text{indicated nominal consumption} - \text{average consumption}) / \text{consumption adjustment time}$$

Change in nominal consumption is an inflow which accumulates into the stock of average consumption. By deducting what people spend over time (average consumption) from disposable income (income after tax); saving is remained as a residual (Table 1-equation 11):

$$\text{Savings} = \text{disposable income} - \text{average consumption}$$

And

**Saving rate = (saving /disposable income)\*100**

### **3.2.4 Overview of New Household Sector**

Returning to the hypothesis, the new version of household sector structure has some differences with the original one in ML. The first one is categorizing the consumption into two different concepts.

The nature of consumption is always changed by human needs. In particular, consumption has a dynamic character based on the nature of society and cultural contexts. As a result there are different consumption classifications and one of them is based on people's basic needs. According to this, consumption is divided into two parts: **essential and discretionary (non-necessity)**, but those terms are very theoretical in the economy. The first one involves total people's need based on the basic nature such as food, shelter and clothing (U.S. Department of Labor 2006). On the other hand, discretionary consumption consists of more sophisticated structure of physiological needs based on social, cultural and individual tastes.

In economics, the consumption function is a mathematical function which is used to state consumer spending and it was developed by John Maynard Keynes (Keynes 1936). The amount of total consumption in each economy can be calculated by this function. The function can be written in different ways, and one of the most basic ways to present it is:

$$C = c_0 + c_1 Y_d$$

Where

**C = total consumption,**

**c<sub>0</sub> = autonomous consumption (c<sub>0</sub> > 0),**

**c<sub>1</sub> is the marginal propensity to consume**

And

**Y<sub>d</sub> = disposable income (income after government intervention – benefits, taxes and transfer payments)**

Autonomous consumption is a term which interprets consumption when there is no (zero) income. Whereas, the propensity to consume (PC), estimates the rate at which

consumption is changing when income is changing. So as income increases, consumption increases. However, Keynes mentioned that the increases (for income and consumption) are not equal, according to him, "as income increases, consumption increases but not by as much as the increase in income".

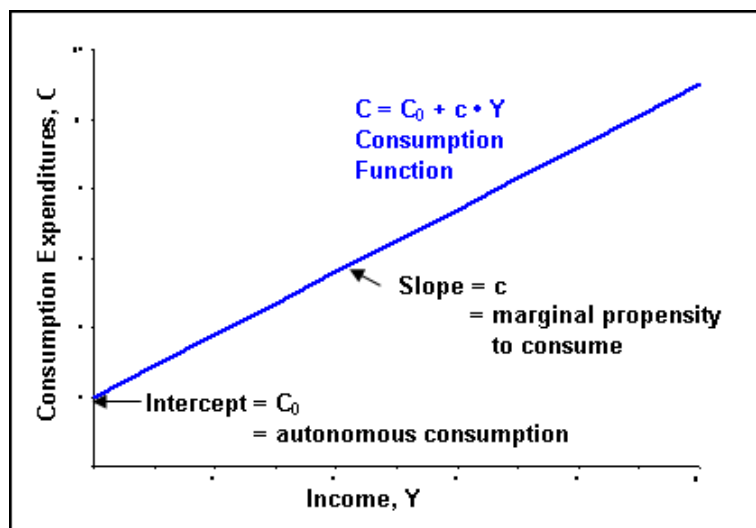


Figure 7: Consumption Function

Source: (Intermediate Macroeconomics 2004)

According to above discussion and the graph in Figure 7, even if people have no income they have such an autonomous consumption which is constant and it can deliver the meaning of people's essential needs. If they are not able to finance their essential consumption, they have to borrow it from another source like banks, government.... This perception is used in the new model to differentiate people's consumption.

Furthermore, the new model is extended by influencing the effect of prices on consumption as well as interest rate. In other words; the new model represents household's decisions on consuming more or less when prices increase or decrease. (Radzicki, Pavlov, and Nicholas 2006)

Figure 8 shows a new household sector module which demonstrates how essential and discretionary consumption parts interact with each other.

Time horizon for simulations and to observe the historical behavior of the reference mode validation in this model is from 1980 (highest percentage of the personal saving rate in the US) to 2011.

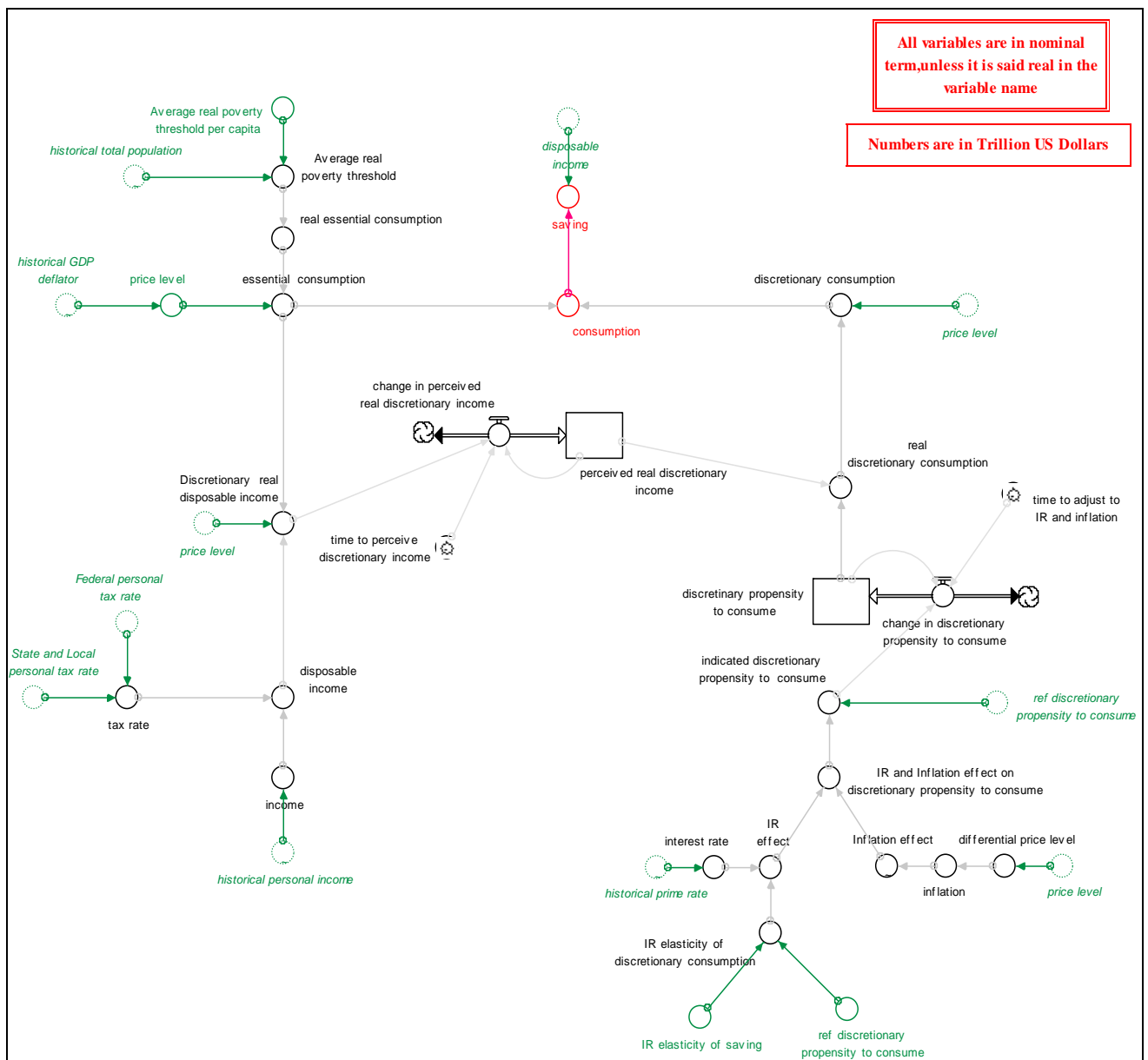


Figure 8: Proposed New Household Sector

\* NOTE: Green color variables are exogenous inputs (e.g. historical data, calculations or estimations); Red color variables are outputs (results) of the model.

### 3.2.5 New Household Sector Equations

#### 3.2.5.1 Saving definition

It is important to identify the main determinants of consumption and saving so that it is more understandable to explain the reasons which are behind the current model in Figure 8.

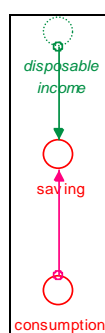


Figure 9: Saving definition

Saving is the difference between disposable income and consumption in Figure 9. In other words, saving is income not spent or deferred consumption. Household saving are calculated as the residual in households' accounting so:

$$\text{Saving} = \text{disposable income} - \text{consumption}$$

A three side relationship among saving, consumption and income, is the key determinant of the amount of household savings (stock of personal saving). On the first side, given a certain amount of income and the decision to buy goods and services (consumption) negatively influences saving. Then saving gently adjust to consumption and income (Piana 2001). An additional feature of consumption-saving is that consumers conform their consuming regularly to income changes (Fisher 2001).



### 3.2.5.2 Consumption definition

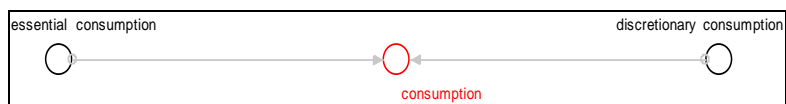


Figure 10: Consumption definition

Consumption is the value of goods and services which are bought by people. Individual buying performances are changed over time and space. Consumption is normally the largest GDP component. Some economists judge the economic performance of their country mainly in terms of consumption level and consumption dynamics.

In the new model, consumption is sum of essential and discretionary consumption (Figure 10). Essential consumption is what people need to live such as food, housing and clothing (U.S. Department of Labor 2006). On the other hand, discretionary vs. essential shows what people buy based on non essential needs which would include (but not limited) to eating out, maids, gym memberships, travel, hobbies, pets, household furnishings, charity, etc. As noted previously, people have essential consumption even if they have zero income, in which case people satisfy by borrowing. It is assumed that people have certain essential consumption. So:

$$\text{Consumption} = \text{Essential Consumption} + \text{Discretionary Consumption}$$

This part of the model is the first distinguish between two models. A related hypothesis of ML indicated consumption as a quantity that adjusts gradually to changes on disposable income and interest rates. However, the current model split it to two different concepts (essential and discretionary). This new version of consumption lets us evaluate people consumption and saving behavior more accurately because essential grows as prices increase, then having an impact on remainder of income, which can be spent on discretionary part.

### 3.2.5.3 Essential consumption

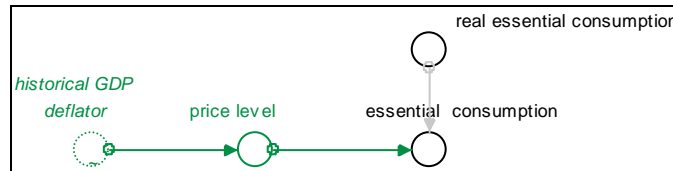


Figure 11: Essential Consumption

Figure 11 shows that how essential consumption (as nominal value) is calculated:

$$\text{Essential Consumption} = \text{real essential consumption} * \text{price level}$$

### 3.2.5.4 Price level

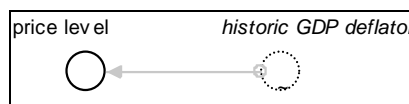


Figure 12: Price level

The price level or price index is a general level of prices for goods and services in an economy.

$$\text{Price level} = \text{Historic GDP deflator} / \text{INIT (historic GDP deflator)}$$

Figure 13 shows the historical GDP deflator which is used in the model. The price level variable re-adjusts the base period of the GDP deflator. The price level will be equal to 1.00 when the simulation begins, but will follow exactly the same pattern as the deflator.

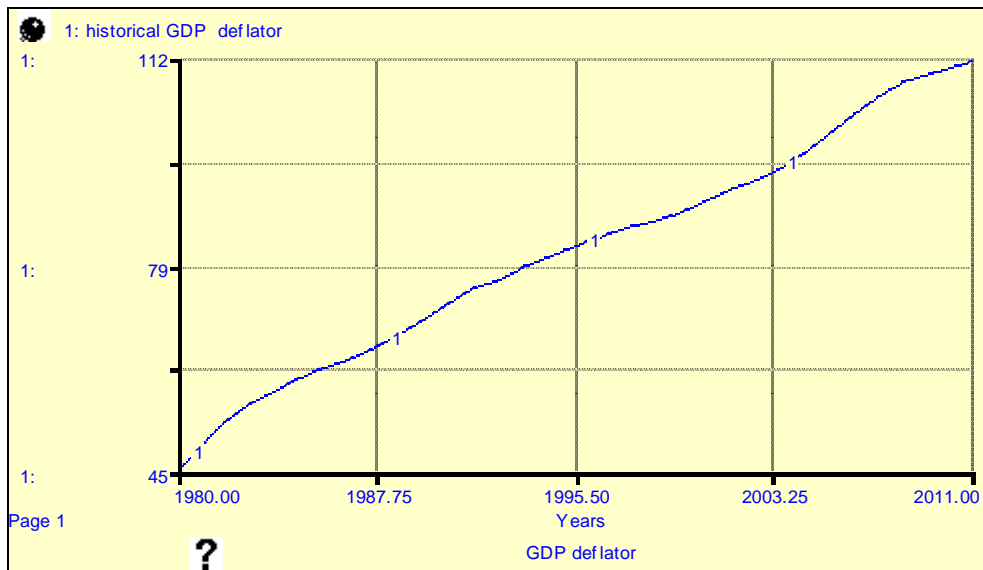


Figure 13: The US GDP deflator (1980-2011)

Source: NIPA Table 7.1 (Bureau of Economic Analysis 2011)

So the GDP deflator is an economic measure that indicates the cost of goods produced in an economy concerning to the purchasing power of the dollar. In the U.S. it begins from 48 in 1980 to 112 in 2011, which means prices have been raised during last three decades and it can increase people's basic needs consumption. So they should pay more for the same basket of daily necessities (essential) as prices go up. It causes that the amount of money that they can spend or save on discretionary goods and services decrease.

### 3.2.5.5 Discretionary consumption

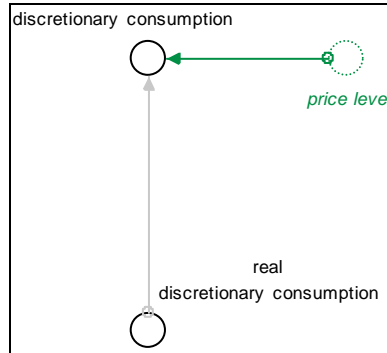


Figure 14: Discretionary consumption

From the other side of the model, discretionary consumption (in nominal value) is calculated as below:

$$\text{Discretionary Consumption} = \text{real discretionary consumption} * \text{price level}$$

It is important to observe that consumption from household sector in ML is part of demand side with nominal terms. For that reason essential and discretionary consumption in this model are calculated in nominal values.

### 3.2.5.6 Real essential consumption

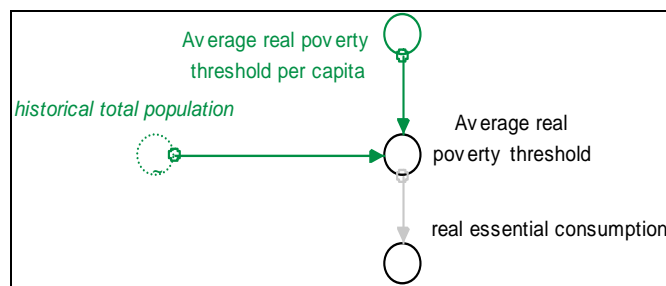


Figure 15: Real Essential Consumption

Back to the left part of the model, real essential consumption is calculated based on minimum needs for each household. As the definition of “Essential” has changed during past years, it is considered that yearly poverty line which has been announced by government can show the minimum budget for living (Figure 15). So it is considered that:

**Real Essential Consumption = Average real poverty threshold** (its aggregate value in trillion \$ per year)

The U.S. poverty thresholds from 1980 to 2011 by size of family and number of related children less than 18 years is collected from United States Census bureau. However, Table 2 reports first and last year as reference.

Numbers in \$

Years	1980	2011
weighted average thresholds for 1 person	4190	11702
weighted average thresholds for 2 persons	5363	15603
weighted average thresholds for 3 persons	6565	17595
weighted average thresholds for 4 persons	8414	23201
weighted average thresholds for 5 persons	9966	27979
weighted average thresholds for 6 persons	11269	32181
weighted average thresholds for 7 persons	12761	37029
weighted average thresholds for 8 persons	14199	41414
weighted average thresholds for 9 persons	16896	49818

Table 2: The US Poverty Thresholds for 1980 and 2011 by size of family and number of related children under 18 years

Source: United States Census bureau (Bureau 2011)

The poverty line is determined by finding the total cost of all the essential resources that an average human being consumes in one year. For calculating this variable weighted average threshold for each person (per capita) in each year is calculated.

Then “weighted average thresholds per person per year” is divided by price level and it (its real value) defines a constant number around 2463 \$ per person (per capita). So by multiplying this constant number (per capita) and historical data of total population, “average

real poverty threshold” for total population (its aggregate value) in each year is evaluated. This variable is used as real essential consumption in Figure 15.

**Average real poverty threshold =Average real poverty threshold per capita\*historical total population**

### 3.2.5.7 Real discretionary consumption

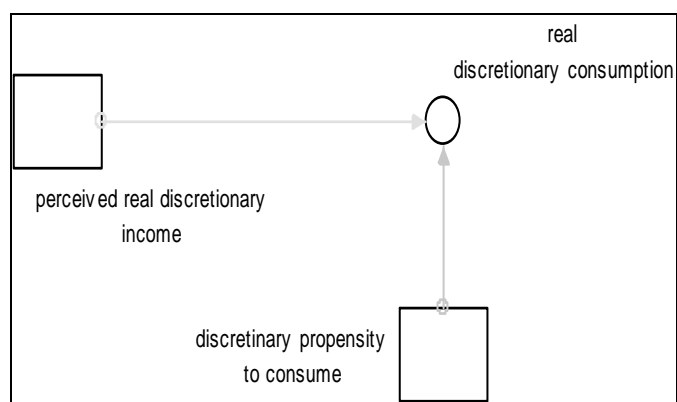


Figure 16: Real Discretionary Consumption

After interpreting real essential consumption, real discretionary consumption should be defined. It is identified based on discretionary propensity to consume and perceived real discretionary income in Figure 16. The equation which represents real discretionary consumption is:

**Real Discretionary Consumption = Perceived real discretionary income\*discretionary propensity to consume**

### 3.2.5.8 Perceived real discretionary income

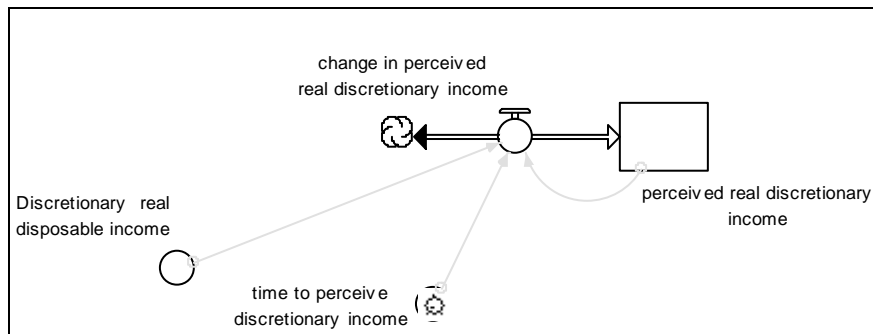


Figure 17: Perceived Real Discretionary Income

In Figure 17 the stock of perceived real discretionary income is changed by its flow which is the difference between the stock and its goal (discretionary real disposable income) during adjustment time to perceive income, which is assumed 3 months by author. So:

**Change in perceived real discretionary income = (Discretionary real disposable income - perceived real discretionary income)/time to perceive discretionary income**

### 3.2.5.9 Discretionary real disposable income

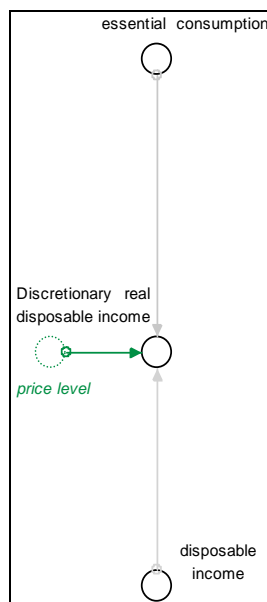


Figure 18: Discretionary Real Disposable income

This part of structure is focused on modeling how consumers distribute their partial discretionary income against different consumption needs.

Discretionary Real Disposable income (Figure 18) includes money which can be spent on luxury items, vacations and non-essential goods and services. It defines by deducting people's essential need consumption from what they earn as disposable income (income after taxes). So the equation for this variable is:

$$\text{Discretionary real disposable income} = (\text{disposable income} - \text{essential consumption}) / \text{price level}$$



### 3.2.5.10 Disposable income

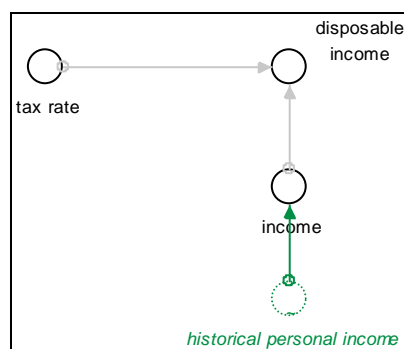


Figure 19: Disposable Income

If it is considered that people contribute their budget for different types of goods or services (e.g. food, home expenditure...) then higher income would mean higher discretionary income and consumption on each category. On the other hand, households with lower income would allocate a higher level of income for essential needs (and expenditure would follow), they would be forced to reduce their discretionary income and purchases (Piana 2001). “In theory, the income tax discourages saving and, relatively, encourages present consumption” (McNulty 2000). So tax rate is one of key variables in the model (and ML), which lets people to consume what is left over their income after paying taxes. Then disposable income in Figure 19 is calculated as:

$$\text{Disposable income} = \text{income} * (1 - \text{income tax rate}/100)$$

Table 3 shows historical personal income and its disposition from NIPA (Bureau of Economic Analysis). Total personal income (line1) of below table is used in the model as historical data. Table 3 shows just first and last years for reference.

<b>Table 2.1. Personal Income and Its Disposition</b>		[billions of dollars]		
<b>Line</b>			<b>1980</b>	<b>2011</b>
<b>1</b>	<b>Personal income</b>	<b>A065RC1</b>	<b>2,301.5</b>	<b>13,005.3</b>
2	Compensation of employees, received	W209RC1	1,647.6	8,292.7
3	Wage and salary disbursements	A576RC1	1,373.5	6,683.2
4	Private industries	A132RC1	1,112.0	5,492.9
5	Government	B202RC1	261.5	1,190.3
6	Supplements to wages and salaries	A038RC1	274.2	1,609.5
7	Employer contributions for employee pension and insurance funds	B040RC1	185.2	1,111.0
8	Employer contributions for government social insurance	B039RC1	88.9	498.5
9	Proprietors' income with inventory valuation and capital consumption adjustments	A041RC1	173.5	1,108.9
10	Farm	B042RC1	11.7	65.9
11	Nonfarm	A045RC1	161.8	1,043.0
12	Rental income of persons with capital consumption adjustment	A048RC1	28.5	403.9
13	Personal income receipts on assets	W210RC1	338.7	1,790.0
14	Personal interest income	A064RC1	274.7	998.1
15	Personal dividend income	B703RC1	64.0	791.9
16	Personal current transfer receipts	A577RC1	279.5	2,336.2
17	Government social benefits to persons	A063RC1	270.8	2,296.8
18	Social security \1\	W823RC1	118.6	713.5
19	Medicare \2\	W824RC1	36.2	553.7
20	Medicaid	W729RC1	23.9	424.3
21	Unemployment insurance	W825RC1	16.1	107.4
22	Veterans' benefits	W826RC1	14.7	63.4
23	Other	W827RC1	61.4	434.6
24	Other current transfer receipts, from business (net)	B931RC1	8.6	39.5

Table 3: Personal Income and Its Disposition in 1980 and 2011

Source: (Bureau of Economic Analysis 2011)

### 3.2.5.11 Tax rates

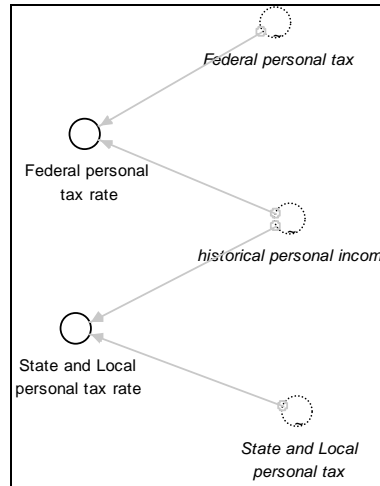


Figure 20: Federal, State and Local tax rate

Taxes are paid in the United States at different levels. These include taxes on income, property, sales, imports, payroll, estates and gifts, as well as various fees.

BEA (Bureau of Economic Analysis) divides personal taxes into two main categories as **Federal** taxes and **State and Local** taxes, which are shown in Table 4. A total personal current tax (line1) of below table is used in the model between 1980 and 2011. Table 4 shows just first and last years for reference.

It should be mentioned that there is another kind of tax called “payroll Tax” or “Federal Insurance Contributions Act tax” which is imposed by the federal government on both employees and employers to fund Social Security and Medicare. “The amount that one pays in payroll taxes throughout one's working career is associated indirectly with the social security benefits annuity that one receives as a retiree. This has caused some to claim that the payroll tax is not a tax because its collection is tied to a benefit” (Hassett 2005).

However, the implementation of personal income and tax which are used in the model is based on definition of NIPA (BEA) in Table 4.

[Billions of dollars]

Line			1980	2010
1	Personal current taxes \1\	W055RC1	298.9	1,193.9
2	Federal	A074RC1	250.0	896.4
3	Income taxes	B231RC1	250.0	896.4
4	Withheld	PTN0181	229.7	883.4
5	Declarations and settlements	PTN1001	63.9	265.8
6	Less: Refunds	PTN2001	43.7	252.9
7	Other taxes \2\	B035RC1	0.0	0.0
8	State and local	W071RC1	48.9	297.5
9	Income taxes	B245RC1	42.6	266.9
10	Motor vehicle licenses	S210301	4.0	16.0
11	Property taxes	S210401	1.2	7.6
12	Other taxes \3\	S210501	1.1	7.0
1. Excludes estate and gift taxes, which are classified in the NIPAs as capital transfers.				
2. Consists of the dividends tax in 1933-34 and of the automobile use tax in 1942-46.				
3. Consists largely of hunting, fishing, and other personal licenses.				

Table 4: Personal Current Tax Receipts

Source: (Bureau of Economic Analysis 2011)Table 3.4

In the above table, two of the main paid taxes are classified in two categories: “Federal taxes” and “State and local taxes”.

Historical data for Federal personal tax and State and Local personal tax from BEA tables are collected then tax rate is calculated by author in Figure 20 and Figure 21 according to the following formulations:

**Federal personal tax rate= Federal personal tax/historical personal income**

And

**State and Local personal tax rate= State and Local personal tax/historical personal income**

Then

**Tax rate = Federal personal tax rate+ State and Local personal tax rate**

Figure 22 shows the graph of calculated tax rate.

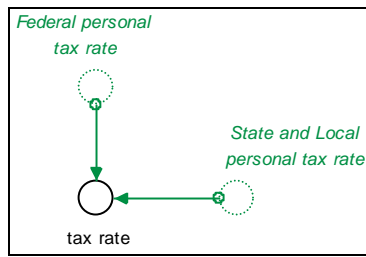


Figure 21: tax rate

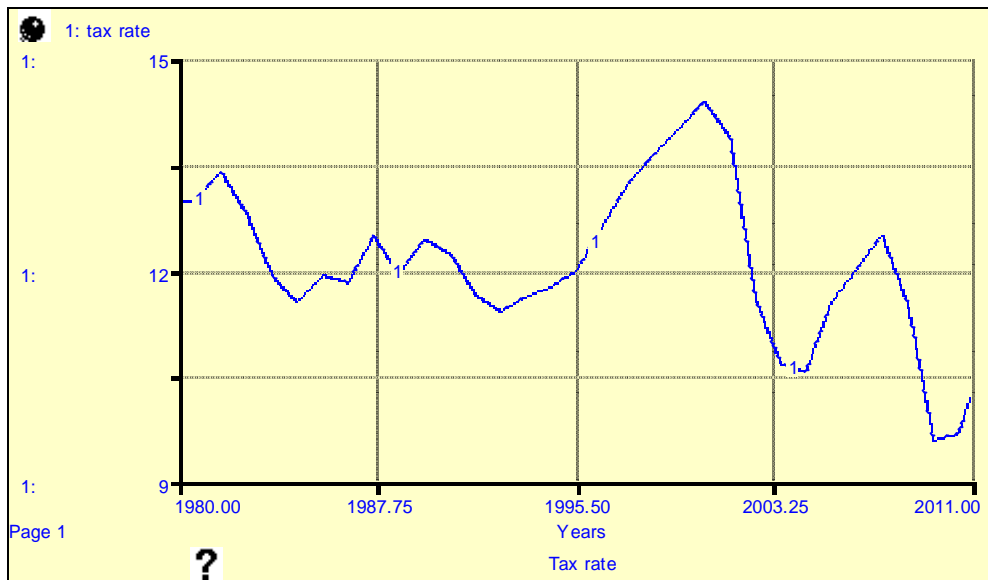


Figure 22: Total Personal income tax rate (1980-2011)

Source: Author's calculation

Then Figure 23 shows the graph of historical personal income based on real data, which is obtained from BEA, and disposable income (historical personal income after tax).

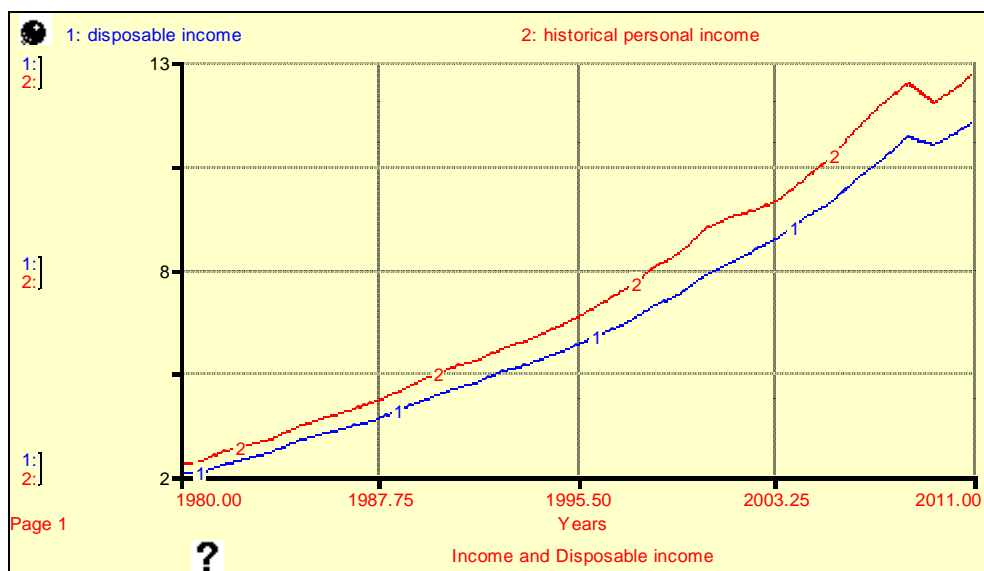


Figure 23: Historical personal income and disposable income (1980-2011)

Source for collecting historical personal data: BEA (Bureau of Economic Analysis 2011)

Income and income tax are very important to assess as any change in income can affect spending dramatically, but not rapidly. Some delays can happen for consumers to postpone their consuming decisions and adjusting spending instructions (adjustment time in Figure 17).

### 3.2.5.12 Discretionary propensity to consume

Allocating discretionary income from income is another different feature of current model compared to ML. In particular, in ML propensity to consume influences total disposable income, whereas in the new aspect of the household sector discretionary disposable income and discretionary propensity to consume are focused. By considering the real life as a pattern for the model, it is assumed that people do not save from their essential or minimum needs. On the other hand, they can decrease their non-essential or discretionary consumption. This description leads us to next step, which is calculating the propensity to

consume. If it is desired to work on consumption-saving pattern, it should be managed by controlling discretionary consumption and discretionary income which create discretionary propensity to consume.

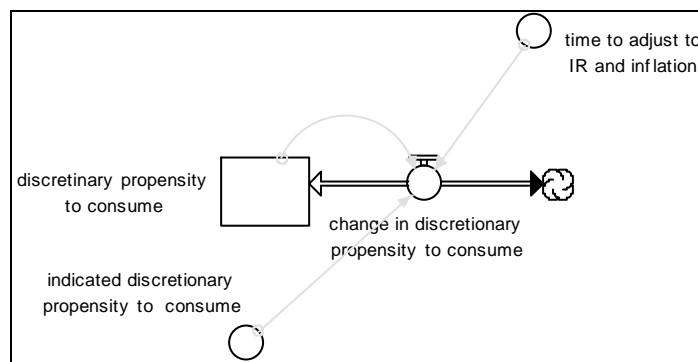


Figure 24: Discretionary propensity to consume

In Figure 24 discretionary propensity to consume is a stock which is changed based on indicated discretionary propensity to consume during adjustment time equal to 1 year. Friedman's original work (Friedman 1957) suggested that consumers take more than 2 years to fully adjust to changes in their disposable income, but it seems that is too long to assume in today's economy. The equation which represents above figure is:

$$\text{Change in discretionary propensity to consume} = (\text{Indicated discretionary propensity to consume} - \text{discretionary propensity to consume}) / \text{time to adjust to IR and inflation}$$

### 3.2.5.13 Indicated discretionary propensity to consume

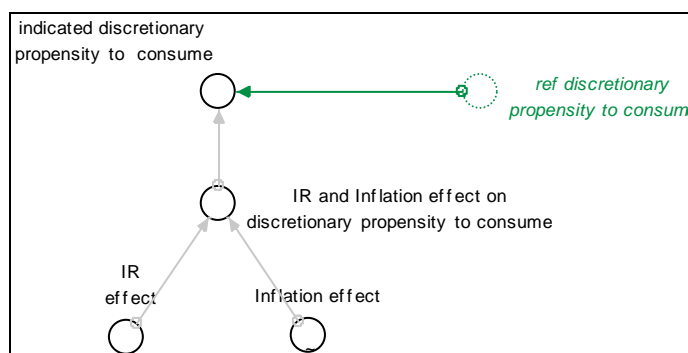


Figure 25: Indicated Discretionary propensity to consume

The propensity to consume represents the percentage of disposable income used for consumption, which by definition, is equal to 1 minus the propensity to save. It is assumed the propensity to save is positively related to the level of income according to “Engel’s law” (Houthakker 1957) and Keynes (Keynes 1936) as well . Making use of interest rate (IR) and inflation effect on reference discretionary propensity to consume, it is built close to its measure in real world. The equation for evaluating this variable is:

**Indicated discretionary Propensity to Consume = reference discretionary propensity to consume\*IR & inflation effect on discretionary propensity to consume**

Reference discretionary propensity to consume (from discretionary income) is assumed 0.92. This estimation is done by using the average value based on below formulas:

**Reference discretionary propensity to consume= Discretionary consumption/discretionary disposable income**

Considering that:

**Discretionary consumption= Historical Personal Consumption - Essential Consumption**

And

**Discretionary disposable income= Disposable Income - Essential Consumption**

Then for example in 1980:

$$(1806.4-523) / (2002.6-523) = 0.86$$

The rest of years are also calculated and the average of all years gives the value of 0.92.

With this in mind, interest rate and inflation effect on discretionary propensity to consume in Figure 25 is:

**IR and inflation effect on discretionary propensity to consume=IR effect\* inflation effect**



### 3.2.5.14 Inflation effect

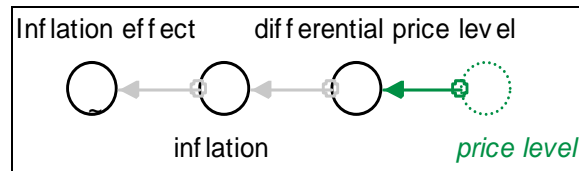


Figure 26: Inflation effect

In reality it is not just the **price** which lets the consumers take decisions while the comparison with other reference prices (present in the memory) makes actions (Piana 2001). So price level (PL) effect is opted on the basis of changes in prices, which is the definition of inflation. So:

$$\text{Differential Price Level} = \text{TREND}(\text{price level}, 1, 0.09)$$

This equation calculates the annual change in price level and it starts with an initial value of 0.09, which is the difference in price level between 1979 and 1980.

Then inflation effect on propensity to consume is evaluated by below graphical function in Figure 27.

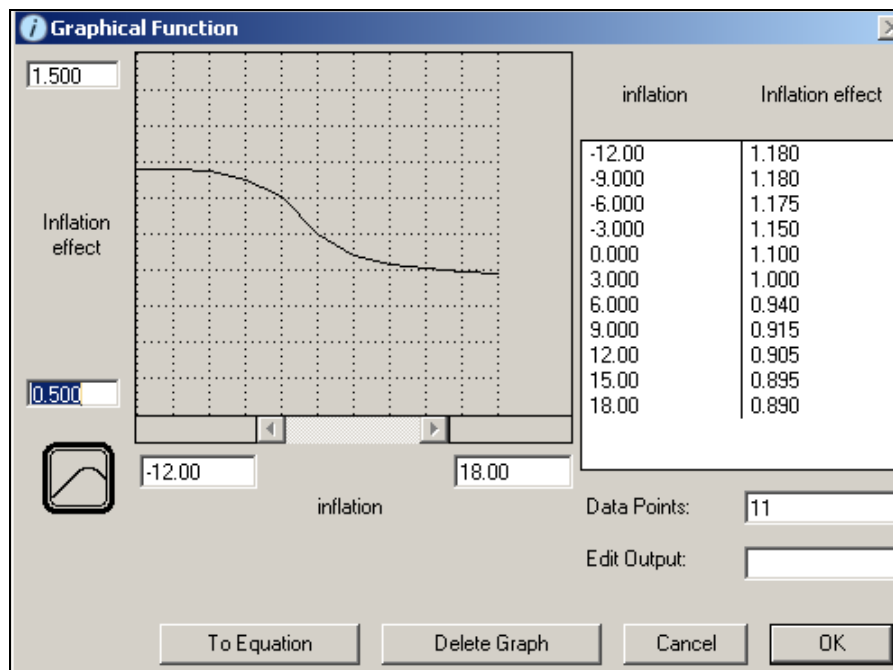


Figure 27: Effect of inflation on discretionary propensity to consume

Source: Author's estimation

Figure 27 reports a general effect shape of inflation on discretionary propensity to consume. It has a logic slope with no effect on consumption when inflation is equal to 3. This value has been chosen as normal by evaluating the average inflation rate in 1980-2011 (Figure 28).

The slope of this function is the most critical parameter in the model. For that reason, so different slopes for numbers below and over 3 are examined to see which of them is more consistent with the model. The graph shows that when inflation is less than number 3 the discretionary propensity to consume and as a result discretionary consumption increase. On the other hand, higher inflation (over 3) leads people to decrease their discretionary propensity to consume and discretionary consumption so that saving increases.

Prices affect the essential part immediately as people cannot resist changes in their basic needs prices. However, in discretionary part, changes in prices (inflation) can direct people to change their discretionary propensity to consume, but during a period of time.

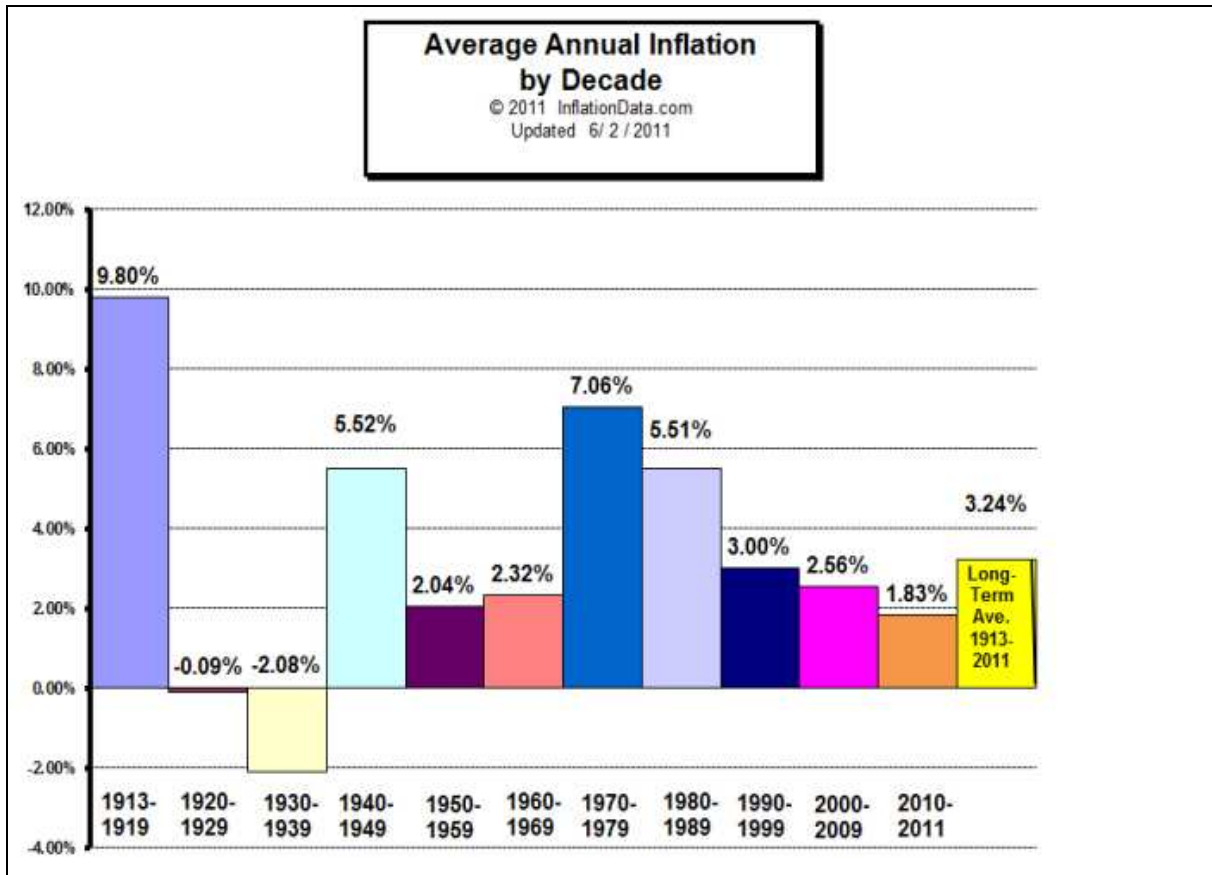


Figure 28: Average annual Inflation by decades in the U.S.

Source: (Intermediate Macroeconomics 2004)

### 3.2.5.15 Interest rate effect

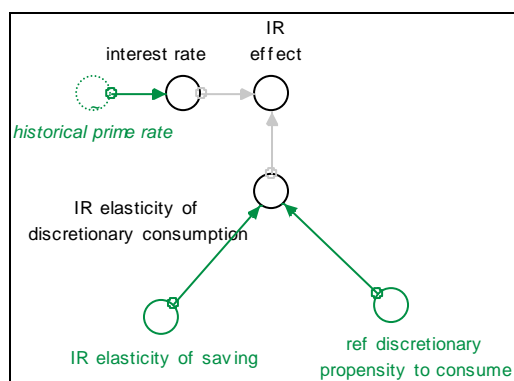


Figure 29: Interest Rate effect

For calculating interest rate effect it is known that people have a tendency to buy luxury and non essential goods and services, which can call discretionary consumption, on credit (e.g. credit cards, loan.). In addition, buying on credit means people should pay interests based on interest rate. So interest rate affects discretionary propensity to consume considerably.

There are some different argues about the effect of interest rate on saving and consumption. Some economists believe that increasing in interest rate encourages people to consume less today and save more. This effect is called the substitution effect, because it incorporates substituting people’s today consumption for tomorrow.

From another point of view, any increase in the interest rate is to “lower the present discounted value (PDV) of people's planned future consumption. In other words, higher interest rates imply that fewer current dollars are needed to fund a given amount of future consumption. Planned future consumption is thus less expensive, making people better off in a lifetime sense, and leading them to consume more today and save less. This effect is named the income effect, and it works in the opposite direction of the substitution effect” (Elmendorf 1996).

As the majority of economists believe in a negative effect on interest rate on household consumption behavior, the same idea is assumed in this current model. So there is

no difference in the new model and ML about taking advantage of interest rate. In other words, the new model took the same structure of interest rate as ML.

Wheat stated that in MacroLab the interest rate elasticity of saving in ML is based on empirical estimates by Colin Wright and that is the same assumption used in the model which is represented in this study, but the interest rate only affects discretionary consumption in the new model.

Wright (Wright 1969) estimated the interest rate elasticity of saving (IRES) to be 0.20. Specified the IRES and the average propensity to consume (APC), it is possible to calculate the interest rate elasticity of consumption (IREC) as following (Wheat 2007 a) :

$$\text{IREC} = - \text{IRES} / (\text{APC} / (1-\text{APC}))$$

Then interest rate elasticity of consumption in the new model is calculates as:

$$\text{Interest rate elasticity of consumption} = - \text{IR elasticity of saving} / (\text{ref discretionary propensity to consume} / (1- \text{ref discretionary propensity to consume}))$$

For forecasting the effect of interest rate on discretionary propensity to consume in Figure 29, following equation is used:

$$\text{IR (Interest Rate) effect} = 1 + ((\text{interest rate} - 8)/8) * \text{IR elasticity of discretionary consumption}$$

Number 8 is an estimation of the average interest rate in the U.S. in 1980-2011, which means if interest rate is equal to 8 it has no effect (effect =1) on discretionary propensity to consume.

The interest rate in the U.S. which is used in the model is based on Prime rate (Figure 30).



Figure 30: The US interest rate based on Prime rate (1980-2011)

Source: Wall Street Journal (FedPrimeRate.com 2011)

Prime rate is a term applied to a reference interest rate used by banks. The majority of finance institutions such as traditional banks, credit unions, thrifts etc use the U.S. Prime rate as an index in order to give short and medium-term loan products.

It should be pointed that when interest rate is equal to 8 and inflation is equal to 3 the variable of “IR and inflation effect” is equal to 1 or no effect.

As it is mentioned before, the propensity to consume is evaluated by effect of interest rate and inflation on a reference value (average discretionary propensity to consume). When the model uses historical data, the reference discretionary propensity to consume is calculated based on that. In contrast, if the model is initialized in equilibrium, the reference discretionary propensity to consume and discretionary propensity to consume become the same and equal to 0.92.

### 3.3 Summary of Section 3

This section surveys the model building process related to previous (ML) household sector and the new version, which both demonstrate the problem dynamically. In addition, the section presents all empirical justifications from the literature to the SD model. Now we move to validate the new model and compare it with the old version in next section.

All models' equations can be seen in Appendix A and Appendix B observes historical data values.

Table 5 proposes a summary of symbolic differences in approaches of new model and the household sector of ML.

<b>Topic</b>	<b>MacroLab model approaches</b>	<b>New contribution model approaches</b>
Income	Disposable income treated endogenously	Disposable income is treated exogenously as historical data
Taxes	Taxes have been calculated endogenously	Taxes are calculated exogenously as historical data
Prices	Consuming choices without considering changes in prices	Consumption depends on changing in prices
interest rate	Interest rate affects total propensity to consume	Interest rate has effect on discretionary propensity to consume
Consumption	Consumption is based on average total consumption	Consumption decisions are different based on people's needs and preferences and budget (essential versus discretionary needs)
Determinants of the household sector	Income, interest rate, time to adjust to new level of interest rate, time to adjust to change in new disposable income	Income(essential and discretionary), prices, interest rate, time to adjust to a new level of interest rate and inflation, time to adjust to new level of discretionary income

Table 5: comparison of the two approaches

## **4. Analysis of the Outcomes of the model**

Model testing and validation are done to make sure that the model is useful and validation test results from the model are matched against existing data.

There are several studies on this topic such as: Tests for building confidence in system dynamics models (Forrester and Senge 1980), Formal aspects of model validity and validation in system dynamics (Barlas 1996), Business Dynamics: Systems Thinking and Modeling for a Complex World (Sterman 2000) and Modeling the Environment (Ford 2009)

This chapter summarized all tests that have been regulated during building the model and after it has been designed.

### **4.1 Unit Consistency & Extreme Condition Test**

Models with equations having inconsistent units are wrong. For that reason, all units in the model were checked from the start to ensure that they are mathematically correct and make logical sense. As a final confirmation the computer program indicated no unit errors. The unit calculations, together with the equations, appear in Appendix A.

Extreme condition knowledge in the model is associated and rate equations have been examined: The implications of negative values for stocks of perceived real discretionary income and discretionary propensity to consume are considered to determine the resulting their effects on the rate equations. Essential consumption considered very high and equal to total disposable income. In addition, adjustment times in the model set to very long time period to see how the behavior is changed. Those conditions cannot happen in real world, but when the model operates under extreme conditions, it demonstrates that it can work under normal conditions as well. Extreme condition tests are conducted several times during testing the final model in order to provide stronger hypothesis.



## 4.2 Behavior Reproduction Test

In order to show the behavior of the model (structure), it is initialized with historical data. As highlighted in Figure 31, a considerable progress has been made with regard to saving rate of the model and historical reference mode.

In Figure 31 behaviors of the household sector of ML (green color), the household sector model of this study (blue color) and the historical saving rate based on NIPA data (red color) are shown.

The results on saving rate are compared (Figure 31) and it seems likely to confirm this study hypothesis. There are some gaps between “average saving rate” and “historical saving rate”, which can be related to other factors than interest rate and inflation.

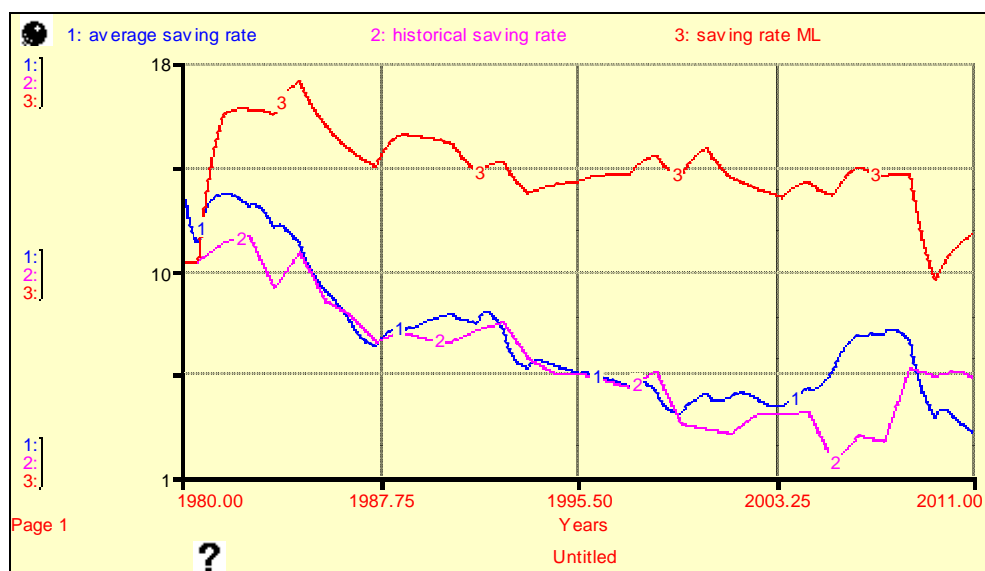


Figure 31: Comparison of replication of historical saving rate by the model in this study versus the household sector of MacroLab

## **4.3 Sensitivity Test**

After creating the model structure, the model was initialized in equilibrium for further testing and analysis. Model testing should be a process of controlled experimentation. For this reason, modelers should initialize their models in equilibrium. Equilibrium means that all stocks in the system are not changing, requiring their inflows and outflows to be equal. Initializing the models in equilibrium facilitates the process of model testing because the system remains in equilibrium until disturbed by imposing test inputs. “If the model begins out of equilibrium, its behavior will confound the response to any test input with the transient behavior induced by the initial disequilibrium” (Sterman 2000).

In order to conduct more sensitivity tests some key parameters in the model are defined and they are simulated with alternative parameter values and results are compared. This test is very important in system dynamics practice because it draws attention to whether modeler is making effective use of judgmental information for modeling (Morecroft 2007).

### **4.3.1 Sensitivity to tax rate**

As can be seen in Figure 32 , saving rate increases to a higher level (simulation no. 2) when the tax rate decrease from 13% to 8% in 1982. The opposite effect on saving rate happens when the tax rate increases. Note that calendar years have no meaning when the model is being tested under equilibrium conditions.

The graph shows by decreasing in taxes people’s savings rise sharply because disposable income and discretionary income go up. After a while they try to adjust their consumption with considering new income (after tax) so they consume more and saving will decrease to lower level, but higher than previous. Differing of this scenario occurs when taxes decrease. It means that, as essential consumption does not change so higher taxes mean fewer remains for discretionary spending and for personal saving.

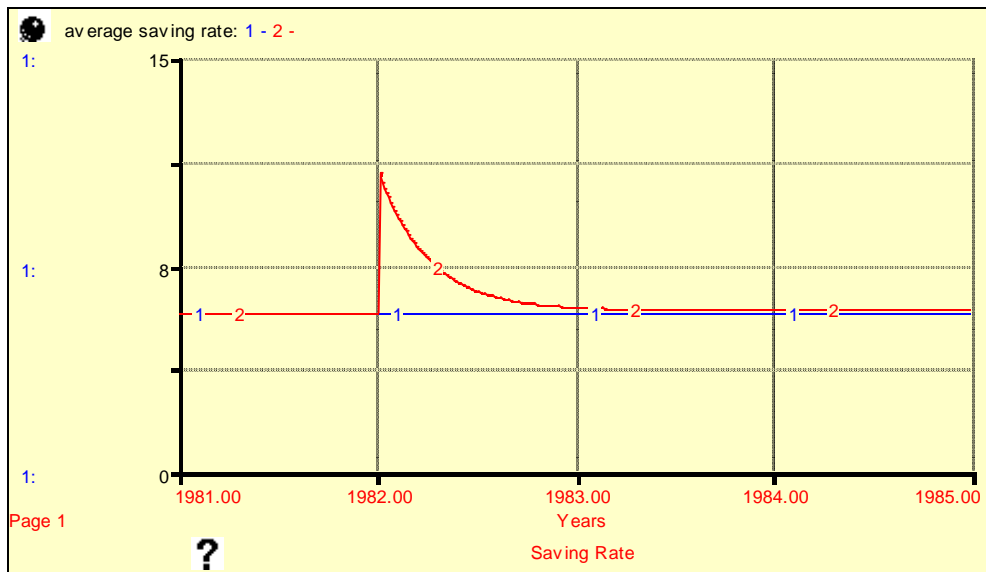


Figure 32: Changes in Tax Rate

### 4.3.2 Sensitivity to interest rate

Interest rate shock test is observed in Figure 33. By increasing the interest rate from 17% to 22% in second year, saving rate increases (simulation no. 2), and opposite of that happens when interest rate decreases. It makes sense in real life, as low interest rates normally discourage people to save their money in banks. At the same time it encourages household to buy more on credit and consequently, more discretionary consumption leads to less savings and saving rate decreases.

On the other hand, higher interest rates encourage people to save more money in their bank accounts.

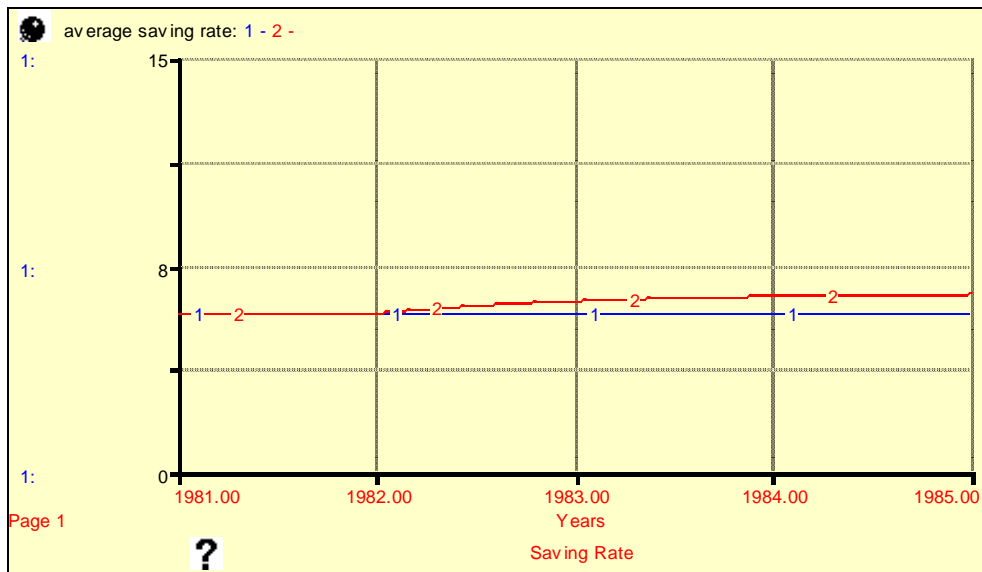


Figure 33: Interest Rate changes

### 4.3.3 Sensitivity to prices (inflation)

The result of shocking the price level is presented in Figure 34. In this part, the deflator value is decreased 0.05 in 1982, which was about 0.55, and that's a 9% decrease in the price level. By decreasing the price level saving rate rises (simulation no.2). As the model is sensitive to the differences in price level, which is changes in prices compared to the previous years (inflation), people's discretionary propensity to consume will go back to its original values.

In contrast, the effect of increasing in price level is a reduction in saving rate which is because people cannot react to the changes immediately and it takes time to change their shopping basket (effect of adjustment time in the model). Afterwards, increase in saving rate is caused by reducing in discretionary propensity to consume (the effect of IR and inflation in the model). Nevertheless, saving rate will be upper than equilibrium mainly because of the effect of price level on essential consumption as well.

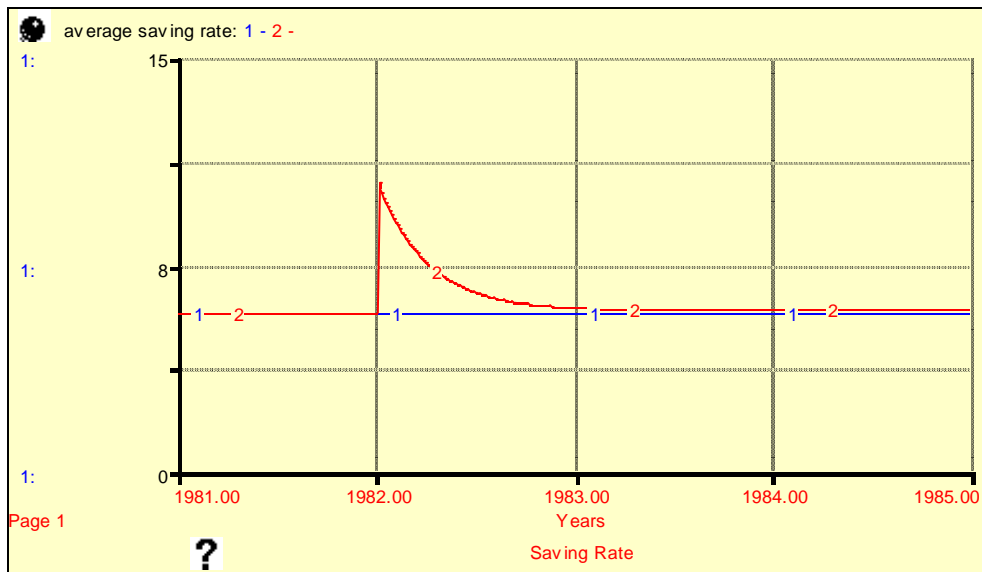


Figure 34: Price Level changes

#### 4.3.4 Sensitivity to reference propensity to consume

From the graph in Figure 35 we can note that by decreasing the reference discretionary propensity to consume (simulation no. 2) saving rate shifts to higher percentage. In other words, it shows lower percentage of buying on discretionary goods and services increase the saving rate. Such a situation may describe that it is a sudden exogenous increase in saving by decreasing in propensity to consume. It can happen perhaps due to fears of a job loss during a recession.

On the other hand, higher reference discretionary propensity to consume leads to lower saving rate.

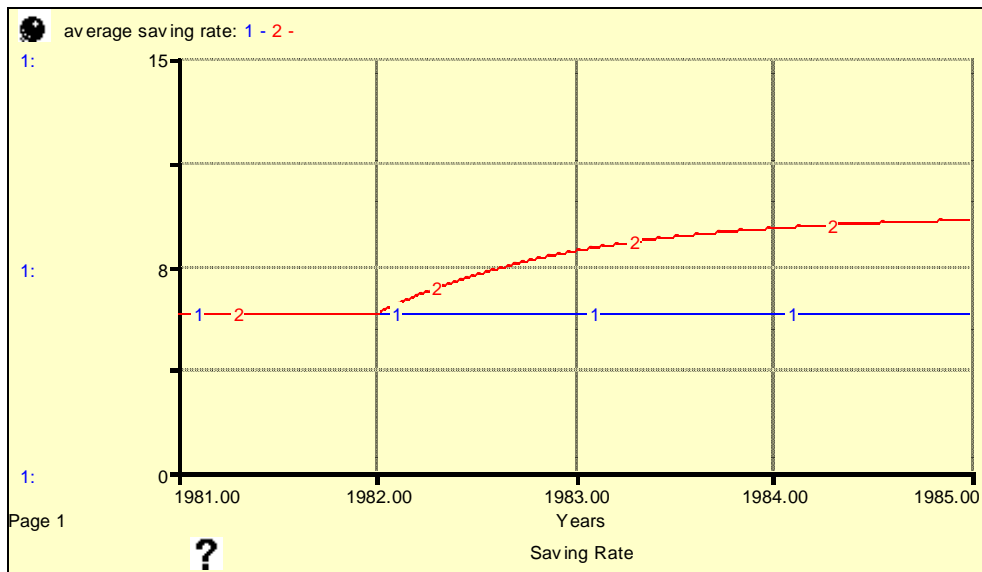


Figure 35: Effect of normal discretionary propensity to consume on saving rate

#### 4.3.5 Sensitivity to adjustment times

In Figure 36 simulations are run when the model is set on historical data. Simulation number one is run when time to adjust to interest rate and inflation is equal to 1 year (assumption in the model). Simulation number 2 is for adjustment time of 0.08 (1 month) and simulation number 3 is for adjustment time of 2 years.

Figure 36 reports that, as the main effect of this adjustment time shifts the graph in time. It means that shorter adjustment time creates more rapid response (shift down in simulation no.2) and longer adjustment time has an opposite effect.

It shows that the model is not very sensitive to this adjustment time, but it can shift the level of saving rate and its higher and lower points in the graph.



Figure 36: Effect of time to adjust to interest rate and inflation

Figure 37 shows the effect of time to perceive discretionary income on saving rate. Simulation number one is for adjustment time of 0.25 (3 months), which is used in the model. Simulation number 2 is for adjustment time of 1 year and simulation number 3 is for adjustment time of 2 years.

The results show that longer adjustment time exaggerates the saving rate, and it shifts up dramatically. So the model is very sensitive to this adjustment time and it may show that if it takes more time until people change their discretionary income (and as a result discretionary consumption) saving rate increase.

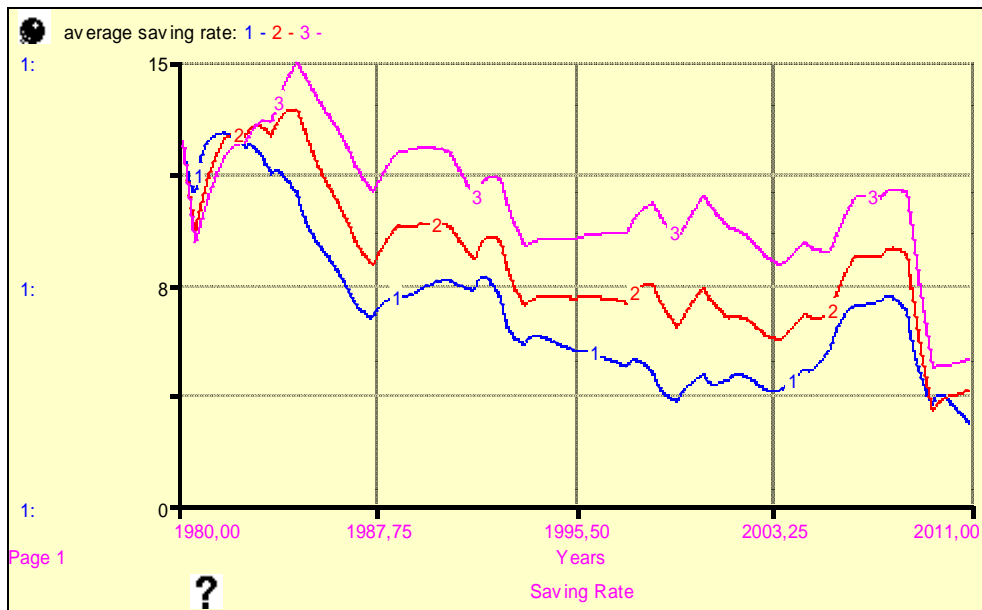


Figure 37: Effect of time to perceive discretionary income

#### 4.4 Testing the graphical function

One of the most important features in the model is the effect of inflation on discretionary propensity to consume and as result consumption and saving. This effect will be imposed in the model by using of the nonlinear graphical function. As stated in the overview of the structure of new model (section 3.2.5.14), normal inflation value is equal to 3, which gives neutral effect on discretionary propensity to consume. Higher inflation values reduce the discretionary propensity to consume while lower inflation has an opposite effect.

To show the sensitivity of the model to the graphical function, the relation between the effects of inflation on discretionary propensity to consume (original graphical function in this study) in Figure 38 is changed according to Figure 39.

A comparison between two graphical functions (in Figure 38 and Figure 39) is shown in Figure 40. In this figure series 1 (blue color) is what is used in the model based on Figure 38 and series 2 (red color) is used for sensitivity test in Figure 39. In particular, this graphical function has higher slope, which means it makes the discretionary propensity to consume more sensitive to inflation.



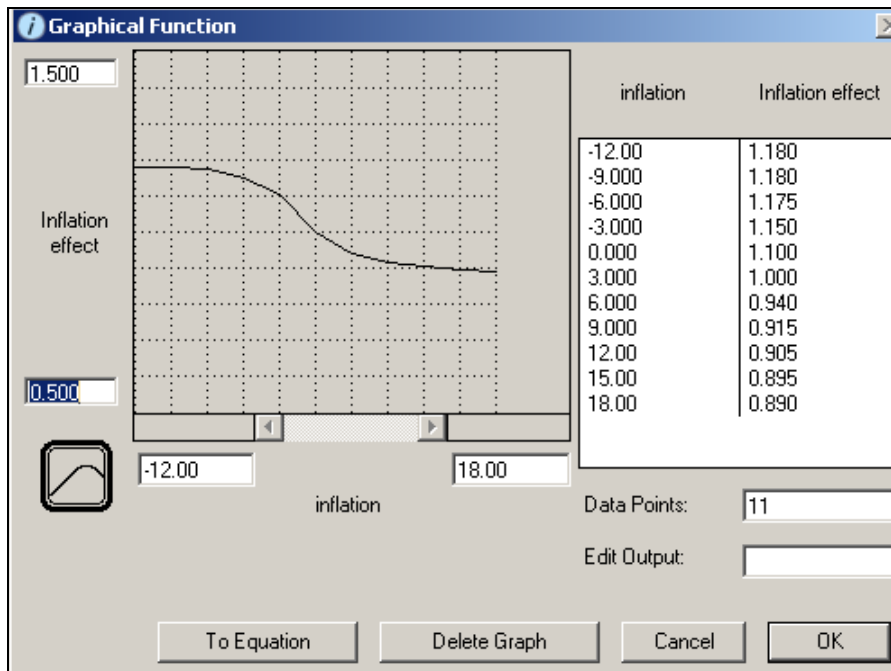


Figure 38: Original graphical function used in the model of this study

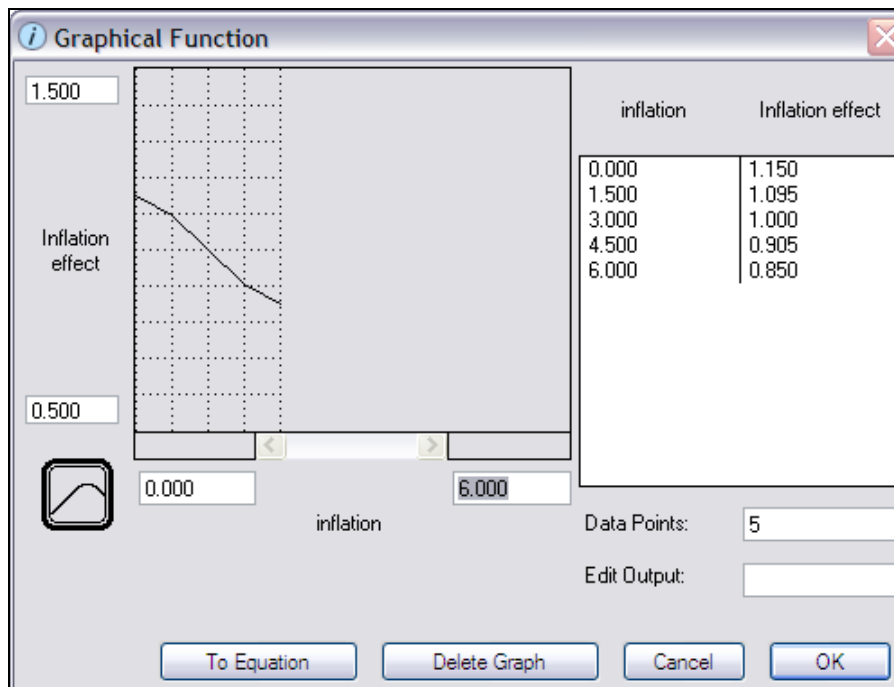


Figure 39: New graphical function for sensitivity test with alternative assumptions for the slope

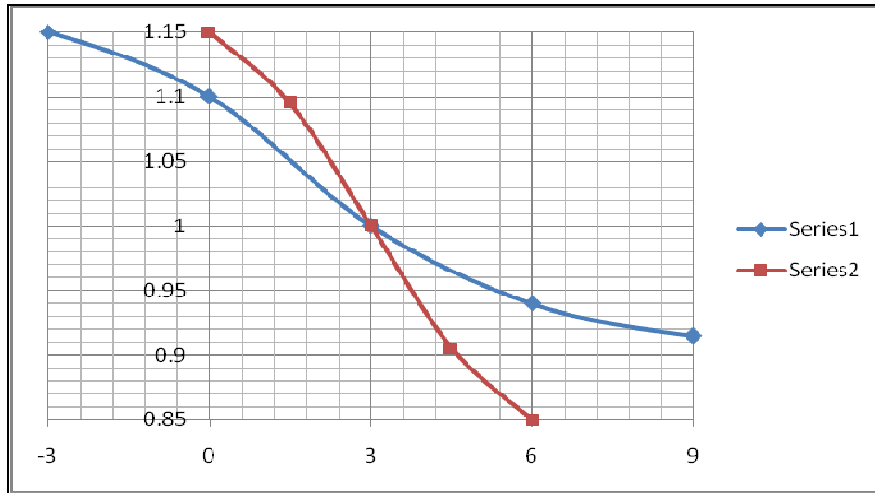


Figure 40: Comparison between the original graphical function and the sensitivity test graphical function and their slopes

The result of running the model with the new graphical function in Figure 39 and its effect on discretionary propensity to consume and as a result on saving rate is demonstrated in Figure 41.

Figure 41 reports that changes in graphical function make the saving rate behavior of model far from the historical data. This confirms that the graphical function that is used in the model is a better representation of reality.

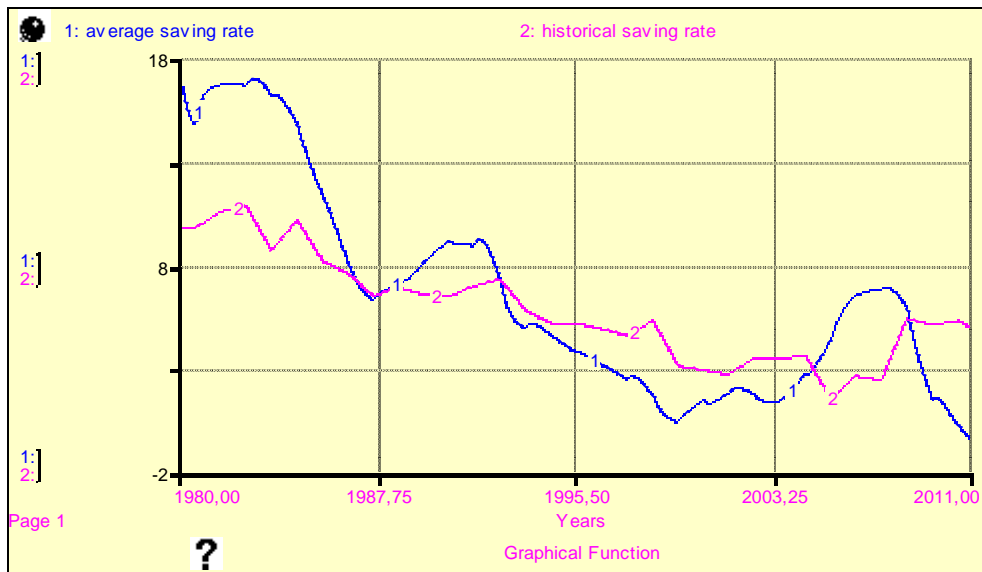


Figure 41: Effect of inflation on discretionary consumption

## 4.5 Structure - behavior Tests

The purpose of doing these tests is to identify how much of change in saving rate is to the price component and how much of it is to the distinction between essential and discretionary consumption.

### 4.5.1 Eliminating the Price effect

As adding the prices and their effects on the model is one of the most distinguishing features between the new model and the household sector of ML, below simulations are done to show how prices and their changes affect the structure of the new model.

Figure 42 is the behavior of the model of this study with the effect of prices as its structure explained in section 3. However, Figure 43 pinpoints how the structure behaves when the price effect is eliminated (inflation has normal effect equal to 1).



Figure 42: Comparison of the behavior of the model and the historical with effect of price level changes



Figure 43: Comparison of the behavior of the model and the historical data with no effect of price level changes

These graphs highlight that price level and inflation have a significant effect on household consumption and saving behavior and eliminating the effect of price impairs the behavior of model in Figure 43 noticeably.

## 4.5.2 Eliminating the Essential consumption effect

To analyze the effect of essential consumption, its value is assumed to be zero and it means that all disposable income goes to discretionary consumption. The effect is shown in Figure 44 and it has resulted in higher saving rate compared to the historical data.

The graph shows that by eliminating essential consumption the discretionary propensity to consume is now interpreted as total propensity to consume; i.e., everything is discretionary, as ML assumed. So, the behavior of the model impairs, but the effect is not significant compared to effect of prices in Figure 43.

An explanation for this insignificant effect is probably because our definition of essential consumption is based on poverty threshold, which is very small part of consumption compared to discretionary part.



Figure 44: The behavior of model with no essential consumption

By comparing between the behavior of model with no effect of price changes in Figure 43 and the behavior of no essential consumption effect (total consumption is discretionary) in Figure 44, it is accomplished that inserting the influence of prices in the household sector is more effective in bringing the realism into the model. However, including essential and discretionary perceptions are useful to interpret the behavior much closer to the historical

data, and by eliminating that effect the behavior of model cannot replicate the historical data behavior. However, eliminating the effect of prices changes the behavior of the model noticeably.

## **5. Discussion and Conclusion**

### **5.1 Discussion**

The main goal of this study was to improve the performance of the household sector of MacroLab. So it can show a better understanding of macroeconomics for those who choose ML as a pedagogical tool. The results have further strengthened our hypothesis that household sector of ML needed to be reformed. This work provides considerable insight into household saving behavior in the U.S. and the results differ to some extent from previous results of this sector.

In fact, in contrast with what was previously built in household sector of ML; it is found that changes in prices have a significant influence on consumption and saving. In addition, behavior on the new model, that is more similar to the reference mode, supports the idea of dividing the consumption to two different concepts (essential and discretionary). So the new model validates the usefulness of dividing household's consumption to essential and discretionary.

In addition, interest rate affects the new model in discretionary part which seems more sensible as in real life interest rate cannot affect people's essential needs directly and considerably. On the other hand, previously in ML interest rate affected total consumption.

The overall direction of results shows trends that could be helpful to learn more about the role of households in the macroeconomics.

## 5.2 Introduction of the new model to students with the Interactive Learning Environment (ILE)

Interactive Learning Environment is an interface which let users understand and communicate with the model better and in a simpler way.

Figure 45 shows the main page overview of ILE for the new version of household sector in this study. It shows that students are able to push the buttons and see the background of problematic behavior while all graphs and a simplified of model is available. Students can start with this page. Each button on that page is a link to the page which is indicated by the button's name.

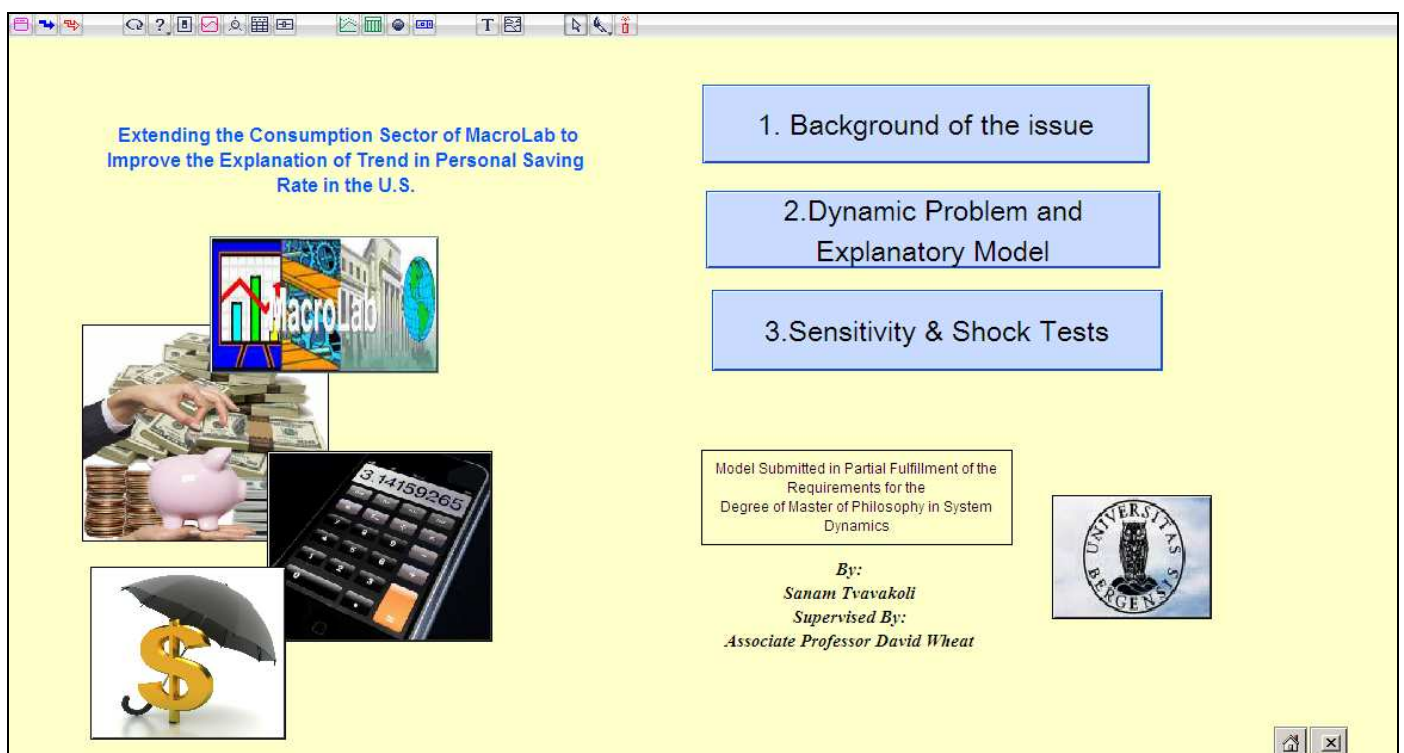


Figure 45: main overview of ILE



Figure 46 is the first page of interface which opens by clicking on “Background of the issues” button. It gives the basic information about the study and its concept.

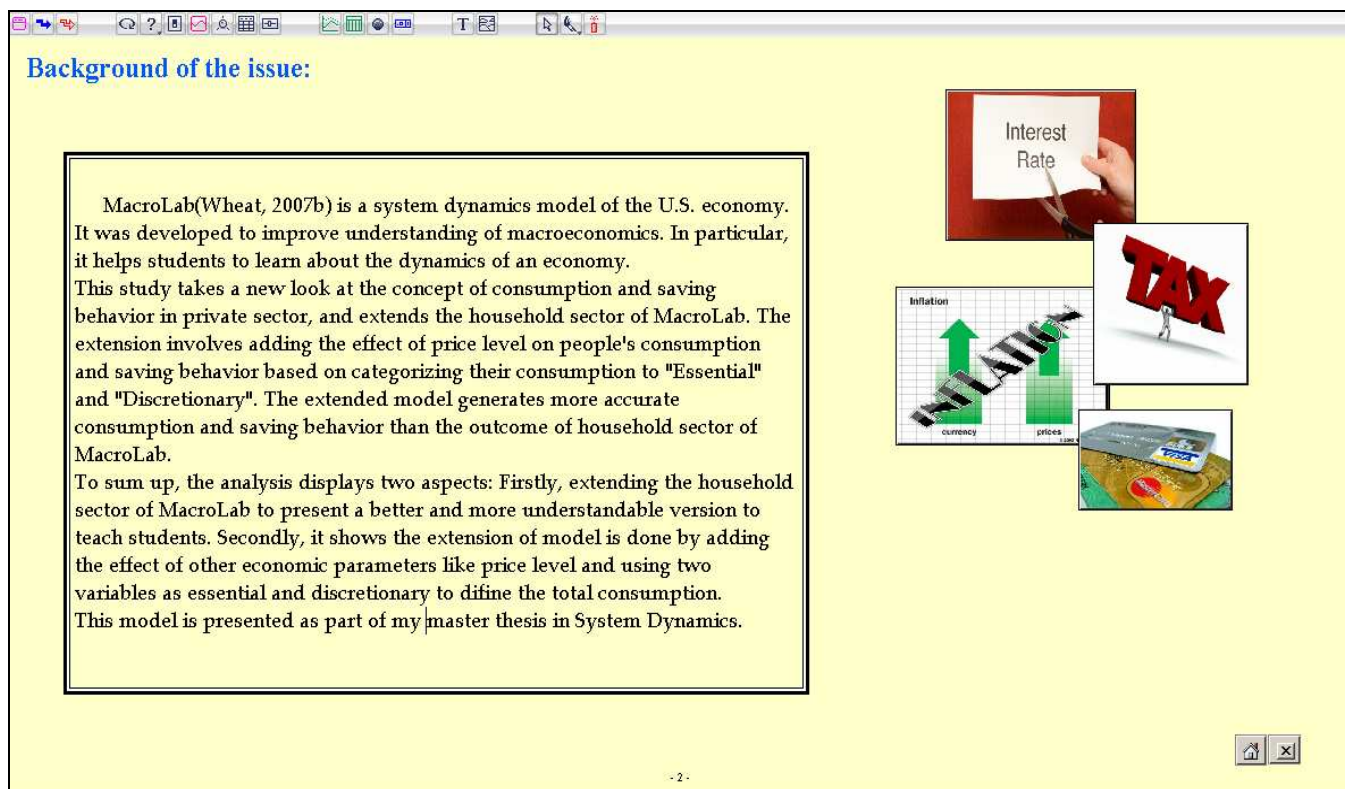


Figure 46: First page of ILE (Background of the issue)

By clicking on the second button (Dynamic Problem and Explanatory model) another page of ILE appears as it is shown in Figure 47. The explanatory of model is kind of story telling which is an efficient feature to help students to understand the model in simple words and step by step. Dynamic problem gives a very short summary of problem (based on the graph in Figure 47) as a story.

**Dynamic Problem and Explanatory Model**

press the below button to read about the Dynamic Problem

Dynamic Problem

Explanatory Model

press the above button to see the storytelling of the new version of consumption sector

1: historical saving rate  
2: saving rate ML

18  
9  
0

1980.00 1987.75 1995.50 2003.25 2011.00

Years

14:34 24. mai 2012

Page 1

Dynamic Problem

Run, Pause, Stop or clear the graph simulation of Dynamic Problem by below buttons

Run  
Pause  
Stop  
Reset

**CONSUMER BEHAVIOR**  
TENTH EDITION

Home X

- 6 -

Figure 47: Second page of ILE (Dynamic Problem and Explanatory Model)

Figure 48 applies after implementing the shock steps and it lets users to simulate the model with or without shocks in different time periods. Students can run the model with historical data or in equilibrium (by using the equilibrium switch).

Adding an interface objects that provide a "laboratory" environment to experiment with the model let users modify model inputs, run simulations and view results with Graphs, Menu Buttons, Numerical Displays, Status Indicators and Switches. So users can communicate with the model better in many different ways.

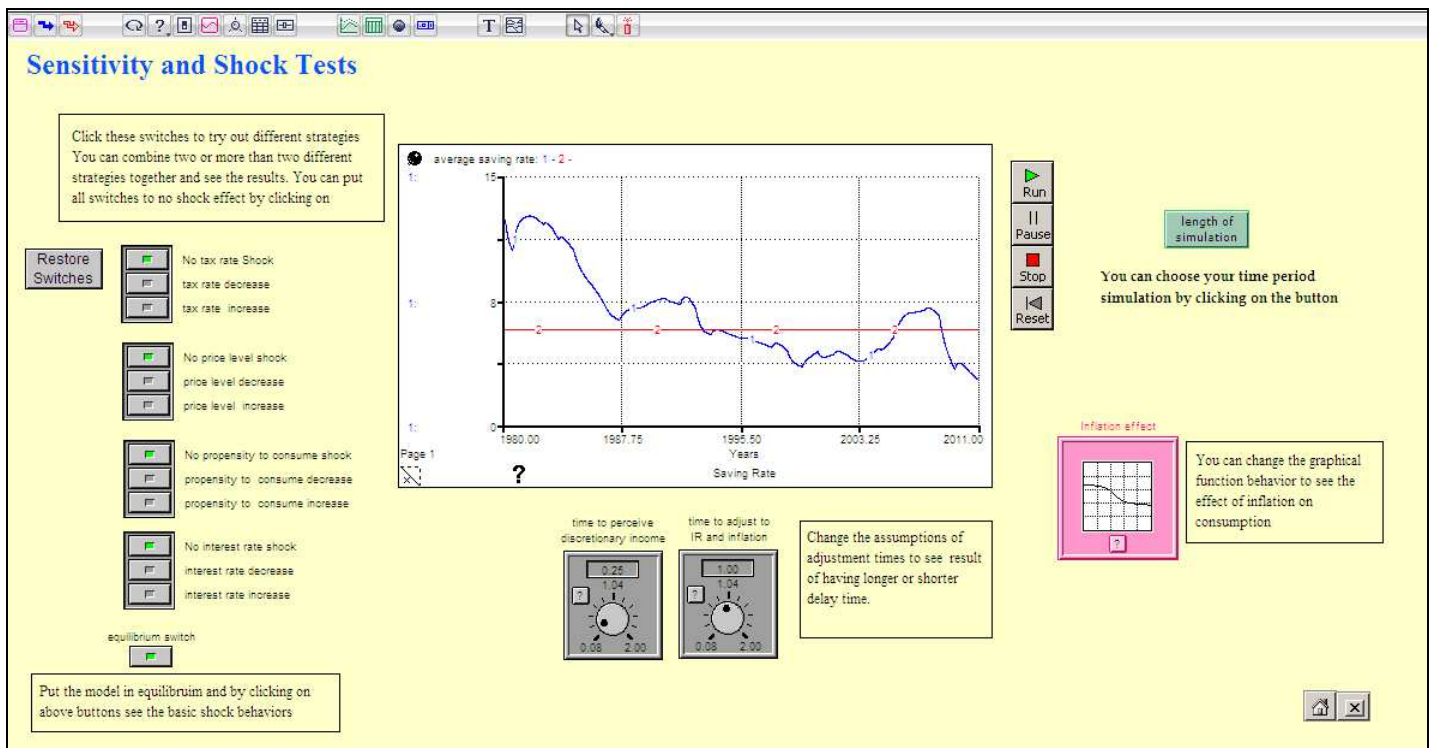


Figure 48: Third page of ILE (Tests)

### 5.3 Limitations and Future Work

It is not easy to cover all household's perspectives about consumption in the model as consumer profile includes variables for motivation, demographics, lifestyle and income, character type, physical and mental profile and consumer preference (like styles, fabric, color, brands, fashion orientation, social and fashion concern, adopter category, and others (Brannon et al. 2000).

It is plausible that a number of limitations may have influenced the results obtained. First, the effect of demographic or lifecycle on saving is not considered in the model. In fact, age and gender of consumers are not primary goals in this research, but on a wider level, gender base differences in consuming may be a good direction for future development of household sector.

Another drawback of this study is that wealth effect did not involve in the structure. When people are richer, or even when they assume themselves to be richer e.g. the evaluated value of their home increases, sharing of consumption can be altered. Especially demand for some discretionary goods and services increases with rising in wealth.

Furthermore, promoting a product by using media can change people's preferences and desire to buy it. It is important to observe that, in a macro model, this only makes if advertising causes an overall increase in consumption.

Another possible source of error is about estimating essential consumption based on poverty thresholds. Further researches and investigations are required to collect exact definition and data for people's essential needs during last 30 years.

Finally, the model does not include the effect of uncertainty in the economy. For example, when recession hits, unemployment rate rises and consumers are less likely to purchase expensive products. As a result, a reduction in consumption increases savings.

Possible explanation for those shortfalls is that people in different positions with respect to income have systematically different structures of consumption. At household level, there are many possible rules set to control monthly, weekly or even daily consumption expenditure. They relate not only to income but also to the other factors (Piana 2001).

I hope that future tests and experiments on MacroLab will prove and complete the findings of this study. Future work should focus on enhancing the quality of household sector by considering above shortfalls. A further important implication is working on the other sectors of ML to see if their outputs are reliable inputs for household sector. It is recommended that further research should be undertaken in replacing new and old versions of household sector in ML and evaluate if more investigations for other sectors are required. At

the end, it is possible to say that the current model can convert real consumer life into the simulation model with formal equations.

## **5.4 Conclusion**

This study has led us to conclude that it is important to understand the characteristics of consumers' different consumption needs with a specified budget or income. In general, the results suggest that people's consumption can be categorized by essential and discretionary needs. It is demonstrated that people can save more from their discretionary consumption and discretionary income. The same is true in real life: people will try to save from every other avenue before they begin cutting basic needs such as food. However, changes to pricing and tax payments can force people to decrease the amount of their discretionary consumption. As a consequence, this is one imperative key in the new model in order to make it more sensible.

Additionally, findings of this study support the idea of the significant effect of price changes on consumer's behavior. Particularly, the new models main contribution is to introduce the effect of pricing and make ML more realistic.

Taken together, these results suggest that adding those parameters to the household sector of ML provides more valuable opportunities to study consumer behavior. The new model can improve knowledge about consumption and saving components so that the research will be constructive to make ML as a more beneficial pedagogical tool.

Despite the limitations discussed earlier in this paper, we can now state that the study provides insight into how the household sector of ML can be improved. The results facilitate our knowledge about that sector so that the new ML (with new household sector) may offer to students and researchers more basis for paying attention to a number of different alternative economic parameters and approaches to consumer behavior.

Returning to the question posed at the beginning of this study, it is now possible to state that we are able to improve the performance of ML and this improvement has been achieved whilst preserving the simplicity of the household sector.

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## Appendix A: List of Equations

List of equations and units for the model is under mentioned.

### New Household Sector Equations:

$$\text{discretinary\_propensity\_to\_consume}(t) = \text{discretinary\_propensity\_to\_consume}(t - dt) + (\text{change\_in\_discretinary\_propensity\_to\_consume}) * dt$$

$$\text{INIT discretinary\_propensity\_to\_consume} = \text{if}(\text{equilibrium\_switch}=0)\text{then}(\text{init}(\text{indicated\_discretinary\_propensity\_to\_consume}))\text{else}(\text{indicated\_discretinary\_propensity\_to\_consume})$$

#### INFLOWS:

$$\text{change\_in\_discretinary\_propensity\_to\_consume} = (\text{indicated\_discretinary\_propensity\_to\_consume} - \text{discretinary\_propensity\_to\_consume}) / \text{time\_to\_adjust\_to\_IR\_and\_inflation}$$

$$\text{perceived\_real\_discretinary\_income}(t) = \text{perceived\_real\_discretinary\_income}(t - dt) + (\text{change\_in\_perceived\_real\_discretinary\_income}) * dt$$

$$\text{INIT perceived\_real\_discretinary\_income} = \text{if}(\text{equilibrium\_switch}=0)\text{then}(\text{init}(\text{Discretinary\_real\_disposable\_income}))\text{else}(\text{Discretinary\_real\_disposable\_income})$$

#### INFLOWS:

$$\text{change\_in\_perceived\_real\_discretinary\_income} = (\text{Discretinary\_real\_disposable\_income} - \text{perceived\_real\_discretinary\_income}) / \text{time\_to\_adjust\_discretinary\_income}$$

$$\text{Average\_propensity\_to\_consume} = \text{consumption} / \text{disposable\_income}$$

$$\text{Average\_real\_poverty\_threshold\_per\_capita} = 2463 / 1000000000000$$



Average\_real\_\_poverty\_threshold = if(equilibrium\_switch=0)  
then(Average\_real\_poverty\_threshold\_per\_capita\*historical\_total\_population)else(Average\_real\_po  
verty\_threshold\_per\_capita\*init(historical\_total\_population))

average\_saving\_rate = (saving/disposable\_income)\*100

consumption = discretionary\_consumption+essential\_\_consumption

differential\_price\_level =  
TREND(price\_level,1,0.09)\*100

discretionary\_consumption = real\_discretionary\_consumption\*price\_level

Discretionary\_\_real\_disposable\_income = (disposable\_income-essential\_\_consumption)/price\_level

disposable\_income = income\*(1-tax\_rate/100)

essential\_\_consumption = real\_essential\_consumption\*price\_level

Federal\_personal\_\_tax\_rate = (Federal\_personal\_tax/historical\_personal\_income)\*100

income =  
if(equilibrium\_switch=0)then(historical\_personal\_income)else(init(historical\_personal\_income))  
indicated\_discretionary\_propensity\_to\_\_consume =  
ref\_discretionary\_propensity\_to\_consume\*IR\_and\_Inflation\_effect\_on\_discretionary\_propensity\_to  
\_\_consume

Inflation = if(equilibrium\_switch=0)then(differential\_price\_level)else(3)

interest\_rate = if(equilibrium\_switch=0)then(historical\_prime\_rate)else(8)+step(-  
5,1982)\*interest\_rate\_decrease+step(5,1982)\*interest\_rate\_increase

IR\_and\_Inflation\_effect\_on\_discretionary\_propensity\_to\_consume = IR\_effect\*Inflation\_effect

IR\_effect = 1+((interest\_rate-8)/8)\*IR\_elasticity\_of\_discretionary\_consumption

**IR\_elasticity\_of\_discretionary\_consumption = -  
IR\_elasticity\_of\_saving/(ref\_discretionary\_propensity\_to\_consume/(1-  
ref\_discretionary\_propensity\_to\_consume))**

**IR\_elasticity\_of\_saving = 0.2**

**price\_level =  
if(equilibrium\_switch=0)then(historical\_GDP\_\_deflator/INIT(historical\_GDP\_\_deflator))else(init(hi  
storical\_GDP\_\_deflator)/INIT(historical\_GDP\_\_deflator))+step(0.05,1982)\*price\_level\_\_increase+  
step(-0.05,1982)\*price\_level\_decrease**

**real\_discretionary\_consumption =  
perceived\_real\_discretionary\_\_income\*discretinary\_propensity\_to\_consume**

**real\_essential\_consumption = Average\_real\_\_poverty\_threshold**

**ref\_discretionary\_propensity\_to\_consume =  
.92+step(.05,1982)\*propensity\_to\_\_consume\_decrease+step(.05,1982)\*propensity\_to\_\_consume  
\_\_increase**

**Saving = disposable\_income-consumption**

**State\_and\_Local\_\_personal\_tax\_rate =  
(State\_and\_Local\_\_personal\_tax/historical\_personal\_income)\*100**

**tax\_rate =  
if(equilibrium\_switch=0)then((Federal\_personal\_\_tax\_rate+State\_and\_Local\_\_personal\_tax\_rate))  
else((init(Federal\_personal\_\_tax\_rate)+init(State\_and\_Local\_\_personal\_tax\_rate)))+step(4,1982)\*t  
ax\_rate\_\_increase+step(-5,1982)\*tax\_rate\_decrease**

**time\_to\_adjust\_to\_IR\_and\_inflation = 1**

**time\_to\_adjust\_\_discretionary\_income = 0.25**

**Federal\_personal\_tax = GRAPH(TIME)**

(1981, 0.25), (1982, 0.291), (1983, 0.295), (1984, 0.286), (1985, 0.301), (1986, 0.336), (1987, 0.35), (1988, 0.393), (1989, 0.403), (1990, 0.452), (1991, 0.47), (1992, 0.461), (1993, 0.475), (1994, 0.506), (1995, 0.543), (1996, 0.586), (1997, 0.663), (1998, 0.744), (1999, 0.825), (2000, 0.893), (2001, 0.996), (2002, 0.992), (2003, 0.829), (2004, 0.774), (2005, 0.799), (2006, 0.932), (2007, 1.05), (2008, 1.17), (2009, 1.10), (2010, 0.857), (2011, 0.896), (2012, 1.09)

**historical\_GDP\_\_deflator = GRAPH(TIME)**

(1980, 43.8), (1981, 47.8), (1982, 52.3), (1983, 55.5), (1984, 57.6), (1985, 59.8), (1986, 61.6), (1987, 63.0), (1988, 64.8), (1989, 67.0), (1990, 69.6), (1991, 72.3), (1992, 74.8), (1993, 76.1), (1994, 78.3), (1995, 79.9), (1996, 81.6), (1997, 83.2), (1998, 84.6), (1999, 85.6), (2000, 86.8), (2001, 88.7), (2002, 90.7), (2003, 92.2), (2004, 94.1), (2005, 96.8), (2006, 100), (2007, 103), (2008, 106), (2009, 109), (2010, 110), (2011, 111), (2012, 112)

**historical\_personal\_income = GRAPH(TIME)**

(1981, 2.30), (1982, 2.58), (1983, 2.77), (1984, 2.95), (1985, 3.27), (1986, 3.50), (1987, 3.70), (1988, 3.92), (1989, 4.23), (1990, 4.56), (1991, 4.85), (1992, 5.03), (1993, 5.35), (1994, 5.57), (1995, 5.87), (1996, 6.20), (1997, 6.59), (1998, 7.00), (1999, 7.53), (2000, 7.91), (2001, 8.56), (2002, 8.88), (2003, 9.06), (2004, 9.38), (2005, 9.94), (2006, 10.5), (2007, 11.3), (2008, 11.9), (2009, 12.5), (2010, 11.9), (2011, 12.4), (2012, 13.0)

**historical\_prime\_rate = GRAPH(TIME)**

(1981, 15.9), (1982, 18.5), (1983, 14.6), (1984, 10.8), (1985, 12.0), (1986, 10.0), (1987, 8.25), (1988, 8.54), (1989, 9.50), (1990, 11.0), (1991, 10.0), (1992, 8.17), (1993, 6.00), (1994, 6.00), (1995, 7.30), (1996, 8.75), (1997, 8.25), (1998, 8.50), (1999, 8.00), (2000, 8.25), (2001, 9.08), (2002, 6.77), (2003, 4.25), (2004, 4.00), (2005, 4.75), (2006, 6.38), (2007, 7.88), (2008, 7.50), (2009, 4.93), (2010, 3.25), (2011, 3.25), (2012, 3.25)

**historical\_saving\_rate = GRAPH(TIME)**

(1981, 9.80), (1982, 10.6), (1983, 10.9), (1984, 8.70), (1985, 10.2), (1986, 8.20), (1987, 7.60), (1988, 6.50), (1989, 6.90), (1990, 6.60), (1991, 6.50), (1992, 7.00), (1993, 7.30), (1994, 5.80), (1995, 5.20), (1996, 5.20), (1997, 4.90), (1998, 4.60), (1999, 5.30), (2000, 3.10), (2001, 2.90), (2002, 2.70), (2003, 3.50), (2004, 3.50), (2005, 3.60), (2006, 1.50), (2007, 2.60), (2008, 2.40), (2009, 5.40), (2010, 5.10), (2011, 5.30), (2012, 4.70)

**historical\_total\_population = GRAPH(TIME)**

(1980, 2.3e+008), (1981, 2.3e+008), (1982, 2.3e+008), (1983, 2.4e+008), (1984, 2.4e+008), (1985, 2.4e+008), (1986, 2.4e+008), (1987, 2.5e+008), (1988, 2.5e+008), (1989, 2.5e+008), (1990, 2.5e+008), (1991, 2.6e+008), (1992, 2.6e+008), (1993, 2.6e+008), (1994, 2.7e+008), (1995, 2.7e+008), (1996, 2.7e+008), (1997, 2.8e+008), (1998, 2.8e+008), (1999, 2.8e+008), (2000, 2.9e+008), (2001, 2.9e+008), (2002, 2.9e+008), (2003, 3e+008), (2004, 3e+008), (2005, 3e+008), (2006, 3.1e+008), (2007, 3.1e+008), (2008, 3.1e+008), (2009, 3.1e+008), (2010, 3.1e+008), (2011, 3.1e+008)

**Historical\_personal\_consumption = GRAPH(TIME)**

(1981, 1.81), (1982, 2.00), (1983, 2.15), (1984, 2.37), (1985, 2.60), (1986, 2.83), (1987, 3.01), (1988, 3.21), (1989, 3.47), (1990, 3.73), (1991, 3.98), (1992, 4.13), (1993, 4.39), (1994, 4.64), (1995, 4.91), (1996, 5.17), (1997, 5.48), (1998, 5.79), (1999, 6.16), (2000, 6.60), (2001, 7.11), (2002, 7.44), (2003, 7.73), (2004, 8.09), (2005, 8.57), (2006, 9.13), (2007, 9.66), (2008, 10.2), (2009, 10.4), (2010, 10.2), (2011, 10.6), (2012, 11.1)

**Inflation\_effect = GRAPH(inflation)**

(-12.0, 1.18), (-9.00, 1.18), (-6.00, 1.18), (-3.00, 1.15), (0.00, 1.10), (3.00, 1.00), (6.00, 0.94), (9.00, 0.915), (12.0, 0.905), (15.0, 0.895), (18.0, 0.89)

**State\_and\_Local\_personal\_tax = GRAPH(TIME)**

(1981, 0.049), (1982, 0.055), (1983, 0.059), (1984, 0.066), (1985, 0.076), (1986, 0.081), (1987, 0.087), (1988, 0.097), (1989, 0.102), (1990, 0.115), (1991, 0.123), (1992, 0.125), (1993, 0.135), (1994, 0.141), (1995, 0.148), (1996, 0.158), (1997, 0.169), (1998, 0.182), (1999, 0.201), (2000, 0.215), (2001, 0.237), (2002, 0.243), (2003, 0.222), (2004, 0.226), (2005, 0.249), (2006, 0.277), (2007, 0.303), (2008, 0.323), (2009, 0.334), (2010, 0.285), (2011, 0.298), (2012, 0.31)

**Total\_historical\_tax\_rate = GRAPH(TIME)**

(1981, 0.39), (1982, 0.4), (1983, 0.4), (1984, 0.39), (1985, 0.4), (1986, 0.4), (1987, 0.41), (1988, 0.4), (1989, 0.39), (1990, 0.4), (1991, 0.4), (1992, 0.41), (1993, 0.42), (1994, 0.43), (1995, 0.43), (1996, 0.44), (1997, 0.43), (1998, 0.42), (1999, 0.41), (2000, 0.41), (2001, 0.41), (2002, 0.42), (2003, 0.42), (2004, 0.41), (2005, 0.4), (2006, 0.4), (2007, 0.4), (2008, 0.4), (2009, 0.42), (2010, 0.42), (2011, 0.42), (2012, 0.42)  
**Discretionary propensity to consume (t) = discretionary propensity to consume (t - dt) + (change in discretionary propensity to consume) \* dt**

**MacroLab Household Sector Equations:**

$$\text{avg\_consumption}(t) = \text{avg\_consumption}(t - dt) + (\text{chg\_in\_nominal\_consumption}) * dt$$

$$\text{INIT avg\_consumption} = \text{indicated\_nominal\_consumption}$$

**INFLOWS:**

$$\text{chg\_in\_nominal\_consumption} = (\text{indicated\_nominal\_consumption} - \text{avg\_consumption}) / \text{consumption\_adj\_time}$$

$$\text{Reference\_propensity\_to\_consume}(t) = \text{Reference\_propensity\_to\_consume}(t - dt)$$

$$\text{INIT Refrence\_propensity\_to\_consume} = (100 - \text{historical\_saving\_rate}) / 100$$

$$\text{consumption\_adj\_time} = 1$$

$$\text{consumption\_ML} = \text{avg\_consumption}$$

$$\text{disposable\_income} = \text{income} * (1 - \text{tax\_rate} / 100)$$

$$\text{disposable\_income\_ML} = \text{disposable\_income}$$

$$\text{Federal\_personal\_tax\_rate} = (\text{Federal\_personal\_tax} / \text{historical\_personal\_income}) * 100$$

$$\text{Income} =$$

$$\text{if}(\text{equilibrium\_switch}=0)\text{then}(\text{historical\_personal\_income})\text{else}(\text{init}(\text{historical\_personal\_income}))$$

$$\text{indicated\_nominal\_consumption} = \text{disposable\_income\_ML} * \text{propensity\_to\_consume}$$

$$\text{interest\_elasticity\_of\_saving\_ML} = 0.2$$

$$\text{interest\_rate} = \text{historical\_prime\_rate}$$

**interest\_rate\_effect\_on\_consumption = 1+((Money\_supply\_interest\_rate-  
init(Money\_supply\_interest\_rate))/init(Money\_supply\_interest\_rate)\*interest\_rate\_elasticity\_of\_consumption\_ML)**

**interest\_rate\_elasticity\_of\_consumption\_ML =  
-interest\_elasticity\_of\_saving\_ML/((Reference\_propensity\_to\_consume)/(1-  
Reference\_propensity\_to\_consume))**

**Money\_supply\_interest\_rate = interest\_rate  
propensity\_to\_consume = (Reference\_propensity\_to\_consume)\*  
smth1(interest\_rate\_effect\_on\_consumption,time\_to\_adjust\_consumption\_to\_interest\_rates)**

**saving\_ML = disposable\_income\_ML-avg\_consumption**

**saving\_rate\_ML = (saving\_ML/disposable\_income)\*100**

**State\_and\_Local\_personal\_tax\_rate =  
(State\_and\_Local\_personal\_tax/historical\_personal\_income)\*100**

**tax\_rate =  
if(equilibrium\_switch=0)then((Federal\_personal\_tax\_rate+State\_and\_Local\_personal\_tax\_rate))  
else((init(Federal\_personal\_tax\_rate)+init(State\_and\_Local\_personal\_tax\_rate)))+step(4,1982)\*t  
ax\_rate\_increase+step(-5,1982)\*tax\_rate\_decrease**

**time\_to\_adjust\_consumption\_to\_interest\_rates = 0.25**

**Federal\_personal\_tax = GRAPH(TIME)  
(1981, 0.25), (1982, 0.291), (1983, 0.295), (1984, 0.286), (1985, 0.301), (1986, 0.336), (1987, 0.35), (1988,  
0.393), (1989, 0.403), (1990, 0.452), (1991, 0.47), (1992, 0.461), (1993, 0.475), (1994, 0.506), (1995,  
0.543), (1996, 0.586), (1997, 0.663), (1998, 0.744), (1999, 0.825), (2000, 0.893), (2001, 0.996), (2002,  
0.992), (2003, 0.829), (2004, 0.774), (2005, 0.799), (2006, 0.932), (2007, 1.05), (2008, 1.17), (2009, 1.10),  
(2010, 0.857), (2011, 0.896), (2012, 1.09)**

historical\_personal\_income = GRAPH(TIME)

(1981, 2.30), (1982, 2.58), (1983, 2.77), (1984, 2.95), (1985, 3.27), (1986, 3.50), (1987, 3.70), (1988, 3.92), (1989, 4.23), (1990, 4.56), (1991, 4.85), (1992, 5.03), (1993, 5.35), (1994, 5.57), (1995, 5.87), (1996, 6.20), (1997, 6.59), (1998, 7.00), (1999, 7.53), (2000, 7.91), (2001, 8.56), (2002, 8.88), (2003, 9.06), (2004, 9.38), (2005, 9.94), (2006, 10.5), (2007, 11.3), (2008, 11.9), (2009, 12.5), (2010, 11.9), (2011, 12.4), (2012, 13.0)

historical\_prime\_rate = GRAPH(TIME)

(1981, 15.9), (1982, 18.5), (1983, 14.6), (1984, 10.8), (1985, 12.0), (1986, 10.0), (1987, 8.25), (1988, 8.54), (1989, 9.50), (1990, 11.0), (1991, 10.0), (1992, 8.17), (1993, 6.00), (1994, 6.00), (1995, 7.30), (1996, 8.75), (1997, 8.25), (1998, 8.50), (1999, 8.00), (2000, 8.25), (2001, 9.08), (2002, 6.77), (2003, 4.25), (2004, 4.00), (2005, 4.75), (2006, 6.38), (2007, 7.88), (2008, 7.50), (2009, 4.93), (2010, 3.25), (2011, 3.25), (2012, 3.25)

historical\_saving\_rate = GRAPH(TIME)

(1981, 9.80), (1982, 10.6), (1983, 10.9), (1984, 8.70), (1985, 10.2), (1986, 8.20), (1987, 7.60), (1988, 6.50), (1989, 6.90), (1990, 6.60), (1991, 6.50), (1992, 7.00), (1993, 7.30), (1994, 5.80), (1995, 5.20), (1996, 5.20), (1997, 4.90), (1998, 4.60), (1999, 5.30), (2000, 3.10), (2001, 2.90), (2002, 2.70), (2003, 3.50), (2004, 3.50), (2005, 3.60), (2006, 1.50), (2007, 2.60), (2008, 2.40), (2009, 5.40), (2010, 5.10), (2011, 5.30), (2012, 4.70)

State\_and\_Local\_\_personal\_tax = GRAPH(TIME)

(1981, 0.049), (1982, 0.055), (1983, 0.059), (1984, 0.066), (1985, 0.076), (1986, 0.081), (1987, 0.087), (1988, 0.097), (1989, 0.102), (1990, 0.115), (1991, 0.123), (1992, 0.125), (1993, 0.135), (1994, 0.141), (1995, 0.148), (1996, 0.158), (1997, 0.169), (1998, 0.182), (1999, 0.201), (2000, 0.215), (2001, 0.237), (2002, 0.243), (2003, 0.222), (2004, 0.226), (2005, 0.249), (2006, 0.277), (2007, 0.303), (2008, 0.323), (2009, 0.334), (2010, 0.285), (2011, 0.298), (2012, 0.31)

Total\_historical\_tax\_rate = GRAPH(TIME)

(1981, 0.39), (1982, 0.4), (1983, 0.4), (1984, 0.39), (1985, 0.4), (1986, 0.4), (1987, 0.41), (1988, 0.4), (1989, 0.39), (1990, 0.4), (1991, 0.4), (1992, 0.41), (1993, 0.42), (1994, 0.43), (1995, 0.43), (1996, 0.44), (1997, 0.43), (1998, 0.42), (1999, 0.41), (2000, 0.41), (2001, 0.41), (2002, 0.42), (2003, 0.42), (2004, 0.41), (2005, 0.4), (2006, 0.4), (2007, 0.4), (2008, 0.4), (2009, 0.42), (2010, 0.42), (2011, 0.42), (2012, 0.42)

## Appendix B: Historical Data

Billions US Dollars

Year	Nominal Income	Taxes	Nominal Disposable income
1980	2301.5	298.9	2002.6
1981	2582.3	345.2	2237.1
1982	2766.8	354.1	2412.7
1983	2952.2	352.3	2599.9
1984	3268.9	377.4	2891.5
1985	3496.7	417.3	3079.4
1986	3696	437.2	3258.8
1987	3924.4	489.1	3435.3
1988	4231.2	504.9	3726.3
1989	4557.5	566.1	3991.4
1990	4846.7	592.7	4254
1991	5031.5	586.6	4444.9
1992	5347.3	610.5	4736.8
1993	5568.1	646.5	4921.6
1994	5874.8	690.5	5184.3
1995	6200.9	743.9	5457
1996	6591.6	832	5759.6
1997	7000.7	926.2	6074.5
1998	7525.4	1026.4	6499
1999	7910.8	1107.5	6803.3
2000	8559.4	1232.3	7327.1
2001	8883.3	1234.8	7648.5
2002	9060.1	1050.4	8009.7
2003	9378.1	1000.3	8377.8
2004	9937.2	1047.8	8889.4
2005	10485.9	1208.6	9277.3
2006	11268.1	1352.4	9915.7
2007	11912.3	1488.7	10423.6
2008	12460.2	1435.7	11024.5
2009	11930.2	1141.4	10788.8
2010	12373.5	1193.9	11179.6
2011	13005.3	1400.3	11605

Table 6: Income and Taxes



Billions US Dollars

Year	Nominal personal Consumption	GDP Deflator in %	Poverty Thresholds
1980	1806.4	47.79	523
1981	2000.4	52.27	582
1982	2148.8	55.46	624
1983	2372.9	57.65	650
1984	2595.2	59.82	684
1985	2825.7	61.63	716
1986	3012.4	62.99	737
1987	3211.9	64.82	772
1988	3469.7	67.05	813
1989	3726.4	69.58	864
1990	3977.3	72.26	919
1991	4131.7	74.82	969
1992	4388.7	76.6	1012
1993	4636.2	78.29	1055
1994	4913.6	79.94	1095
1995	5170.8	81.61	1141
1996	5478.5	83.16	1189
1997	5794.2	84.63	1231
1998	6157.5	85.58	1268
1999	6595.5	86.84	1314
2000	7114.1	88.72	1372
2001	7443.5	90.73	1428
2002	7727.5	92.2	1468
2003	8088.1	94.14	1512
2004	8571.2	96.79	1570
2005	9134.1	100	1638
2006	9659.1	103.23	1708
2007	10174.9	106.23	1775
2008	10432.2	108.58	1845
2009	10236.3	109.73	1846
2010	10586.9	110.99	1872
2011	11055.1	112.1	1996

Table 7: Consumption, poverty threshold and GDP deflator

Year	Prime Rate
1980	15.86
1981	18.51
1982	14.58
1983	10.83
1984	12.00
1985	10.00
1986	8.25
1987	8.54
1988	9.50
1989	11.00
1990	10.00
1991	8.17
1992	6.00
1993	6.00
1994	7.30
1995	8.75
1996	8.25
1997	8.50
1998	8.00
1999	8.25
2000	9.08
2001	6.77
2002	4.25
2003	4.00
2004	4.75
2005	6.38
2006	7.88
2007	7.50
2008	4.93
2009	3.25
2010	3.25

Table 8: Average Prime Rate