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Consumption Responses and Redistributive Implications of Luxury Durable Tax Rebates

by

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Abstract

This paper evaluates the impact of tax rebates on luxury durables, using Thailand's 2011 car tax rebate as a case study. Utilizing a stochastic dynamic model with heterogeneous agents, where cars serve as both luxury goods and illiquid assets, the study finds that the policy effectively boosted consumption by targeting households with a high propensity to spend. However, it was regressive, primarily benefiting high-income households and leading to prolonged negative effects on household spending and saving. Additionally, the policy caused second-hand car prices to drop. This enabled lower-income households to purchase used cars at lower costs, but further prolonged and deepened cuts in non-durable spending and savings . The estimated Elasticity of Intertemporal Substitution (EIS) for Thailand is 0.2, with higher EIS observed among wealthier and older households.

Keywords: durable goods, luxury tax, fiscal policy, elasticity of intertemporal substitution, buffer-stock models, illiquid assets *JEL Codes: D72, D74, P48, Z13*

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1 Introduction

With increasing economic downturns caused by crises and natural disasters, governments worldwide have implemented various fiscal measures, such as cash or in-kind transfers, tax breaks, and rebate programs, to help mitigate the effects of unexpected negative income shocks. At the aggregate level, durable spending typically declines first during downturns, and at the household level, those facing income shocks often cut back on luxury or durable goods first. Consequently, tax rebates on such goods may seem like a straightforward stimulus option. This paper examines the efficiency and redistribution implications of different policy instruments, particularly focusing evaluating the impact of Thailand's car tax rebates, or more generally tax rebates on luxury durable goods, using a heterogeneous-agent stochastic income life-cycle model framework.

Fiscal stimulus involves two key trade-offs. First, there is a trade-off between short-term economic boosting and long-term consumption: a surge in purchases of one good may crowd out savings and reduce demand for other goods. Second, there is a trade-off between efficiency and equity. To maximize stimulating impact, a program should target those with the highest propensity to spend, but these individuals may not be the neediest or those who would gain the most in welfare. Policymakers must, therefore, balance between boosting efficiency with the risk of crowding out other consumption, and also consider redistribution implication.

Early and well-known car tax rebate programs include the "Cash for Clunkers" initiative in the US and France's "Balladurette and Juppette" program. Later, similar programs have been introduced in developing economies where cars are considered luxury goods. For instance, China launched EV subsidies in the 2010s, and the First-Car Tax Rebate Program in Thailand in 2011 to 2012. The Thailand's car tax rebate program saw over a 200 percent increase in car purchases, led to over 1.1 million cars sold in the first year alone. Contrary to consumption smoothing behavior predicted by off-the-shelves consumption and saving models, the stimulus program elicited substantial consumption responses.

Unlike other car tax rebate programs, Thailand's car tax rebate had a significant impact on the second-hand market, as the trade-in of old cars was not required to qualify for the rebate. To evaluate the policy's impact, this study incorporates a two-tier pricing system, differentiating between resale market prices and new car prices. The analysis reveals that the policy's unintended consequences on used-car prices significantly boosted second-hand car purchases among lower-income households after the policy had ended. This, in turn, led to a more pronounced decline in non-durable spending and reduced savings or investment in other assets compared to a scenario without the second-hand price effects. Consequently, the impact of the policy on the second-hand car market and its effects on households is substantial and far from negligible.

The Thailand's car tax rebate was implemented after the major 2011 flood and during the global economic recovery from the 2009 financial crisis. As highlighted by the Lucas critique, counterfactual analyses from reduced-form methods are context-specific. To address these potential confounding factors, this paper employs a structural approach using a heterogeneous-agent stochastic dynamic framework to evaluate the impacts of car tax rebate programs. It also assesses alternative policies, including consumption tax rebates, cash transfers proportional to income, and interest rate hikes in order to evaluate different policy instruments' boosting efficiency and redistributive impacts.

The alternative policy experiments were selected for their potential to stimulate the economy through different channels. The car tax rebate, which influences price, income, and wealth, has the most significant effect on dampening saving due to its direct impact on relative prices of assets. The consumption tax cut mainly affects households through the price channel, effectively boosting consumption via the substitution and income effects. The proportional income tax rebate operates solely through the income channel, while interest rate hikes affect households through the wealth channel, influencing spending based on existing assets.

The experiments show that car tax rebates provide the strongest short-term stimulus via the price, income, and wealth channels, while consumption tax cuts are the next most effective, with a less detrimental effect on savings. Proportional-income cash transfers offer lower immediate stimulus but can boost consumption persistently beyond the policy period without negatively impacting household saving. Interest rate hikes benefit wealthier households but may reduce spending among those with higher debt or strong saving motives, highlighting significant heterogeneity in the Elasticity of Intertemporal Substitution (EIS) among households at different ages and wealth levels.

Using Thailand's car tax rebate as a case study, three key policy outcomes inform the model choices. First, the policy triggered significant spending responses. Second, most participating households were high-income. Lastly, the volume of trade-ins caused a substantial drop in second-hand car prices. These outcomes suggest that the program's effectiveness stemmed from its dual focus: subsidizing large, luxury durable goods, which implicitly targeted individuals with a high propensity to spend. However, the ramifications on the resale market also led to a more widespread impact on lower-income households and a longer-lasting reduction in non-durable spending and savings in subsequent periods.

The proposed model successfully replicates the large and heterogeneous consumption responses observed following the policy. Two key mechanisms drive these outcomes: 1) durable adjustment costs, and 2) non-homothetic preferences. Durable adjustment costs make car purchases infrequent and lumpy, contributing to procyclical aggregate spending. Durable goods are often the first to be cut back during negative income shocks, and substantial positive income shocks are required to overcome these adjustment frictions. The price reductions on cars due to subsidies act as such positive income shocks, leading to significant surges in car demand.

Second, non-homothetic preferences in durable goods, as reflected in a non-linear Engel curve, drive heterogeneous consumption responses. Low-income (or low-wealth) households, due to these non-homothetic preferences, are less likely to own a car and would only consider purchasing one upon reaching a certain wealth threshold. Therefore, income shocks that are not sufficiently large will not change car demand for lower-income households. However, the subsequent drop in resale prices had a trickle-down effect, making second-hand cars more affordable for lower-income households. This also made car ownership more accessible to low-income household.

This non-linear demand aligns with empirical observations where car ownership and spending increase nonlinearly with income or wealth. It also predicts heterogeneity in the Elasticity of Intertemporal Substitution (EIS) across households with different wealth levels. I found the average simulated EIS is equal to 0.25, but heterogeneous among household with varying asset profiles (of liquid and illiquid assets) and age. EIS values are positive and larger for wealthy and older households, while they are negative for low-wealth and younger households.

The remainder of this study is organized as follows: Section 2 reviews related literature. Section 3 provides background on policy, taxation in Thailand, and Thai household data. Section 4 describes the model, its solution, and parameter interpretations. Section 5 outlines the estimation strategy, parameter choices, and identification. Section 6 presents the estimation results, model fit, and policy experiments. Finally, Section 7 discusses the results, limitations, and future work, and Section 8 concludes the study.

2 Literature review

This work is related to a few strands of literature: 1) car subsidy programs, 2) household consumption responses to permanent income shocks, 3) models of consumption and saving with illiquid assets or durables, and 4) elasticity of intertemporal substitution literature.

2.1 Car subsidy programs

Thailand's car tax rebate scheme is similar to car subsidy programs implemented in other countries. For example, the United States' Cars Allowance Rebate System (CARS), commonly known as Cash for Clunkers, and France's Balladurette and Juppette Program both subsidized the replacement of old cars with new ones. The Balladurette and Juppette subsidies were found to increase government revenues in the short run but to cannibalize revenues in the long run (Adda and Cooper, 2000). In contrast, Cash for Clunkers was observed to pull forward future demand by approximately 7 months, with no evidence of impacts on employment, house prices, or household default rates afterward (Mian and Sufi, 2012).

Thailand's car tax rebate policy differs from previous programs in three key ways. First, it did not aim to reduce old car fleets or require trade-ins, resulting in a large influx of old cars into the second-hand market and significant price effects. Second, the price drops were more substantial compared to earlier programs due to higher participation and coverage. Lastly, while previous programs were in upper-income countries, Thailand is an upper-middle-income country where only top 20-30 income percentiles owned cars during the launch of the policy. These differences mean that findings from past programs may not directly apply to Thailand's context. Studying this policy provides valuable insights as more developing economies adopt similar measures, and it offers a unique opportunity to observe household responses to large car price shocks and a drop of car prices in the resale market.

2.2 Household consumption responses

This paper relates to research on household spending in response to permanent income shocks. Recent studies, including Shapiro and Slemrod (2009), Parker et al. (2013), and Gelman et al. (2019), explore how households react to income tax rebates or price shocks. Shapiro and Slemrod (2009) found that households with different balance sheet conditions spent income tax rebates in various ways, from paying debts to saving or consuming them. Gelman et al. (2019) studied responses to income shocks from falling gasoline prices and found a marginal propensity to spend of 1.

This study add to this strand of literature but takes a structural model approach. Unlike income tax rebates or price drops in non-durable goods, a car tax rebate affects households differently due to the dual role of durable goods as both consumable items and illiquid assets. The adjustment friction of durable goods can lead to highly nonlinear consumption responses—very large changes for some households when shocks are significant, or no change for others.

2.3 Illiquid assets and durable goods

This paper relates to research on household consumption responses to income shocks when durable goods or illiquid assets that carries adjustment costs. Standard consumption theories, such as rational expectations and life-cycle models with a risk-free asset, predict negligible marginal propensity to consume from transitory income shocks. However, models incorporating illiquid assets with adjustment costs can better explain instances where households exhibit significant consumption responses. Notable studies in this area include Kaplan and Violante (2014) and Berger et al. (2018), which use partial equilibrium models to examine consumption and saving decisions in markets with illiquid assets and adjustment frictions.

This study is similar to these two but different in that it focuses on a car market where cars are not a necessity and households have a non-linear Engel curve in car demands as empirically observed (Havránek, 2015). Fernandez-Villaverde and Krueger (2011) and more recent work by Parodi (2023) has incorporated durables as luxury goods in the structural life-cycle model context. McKay and Wieland (2021) also studied the role of durable adjustment on monetary policy transmission. This paper contributes to the literature by evaluating policy responses in the context of the second-hand market and within a developing country setting with limited borrowing constraints.

2.4 Elasticity of intertemporal substitution.

This study contributes to the literature on the Elasticity of Intertemporal Substitution (EIS) by offering a theoretical framework that explains how EIS varies with wealth, asset holdings, and allocation throughout the life cycle. It highlights how adjustment frictions and non-homothetic preferences drive heterogeneous EIS across households. The approach of calculating simulated EIS and consumption responses is similar to that of Parodi (2024), who calculated consumption responses to tax reforms.

Empirical studies have shown wide-ranging EIS estimates across different countries and wealth levels. Two main factors, wealth and stock market participation, have been identified as reconciling this variation. Blundell et al. (1994) and Attanasio and Weber (1995) found that wealthier households tend to have higher EIS. Additionally, households with greater wealth, often stockholders, generally exhibit higher EIS compared to low-wealth households (Havranek et al., 2015).

At the aggregate level, countries with lower stock market participation tend to report smaller EIS. The average EIS reported in empirical studies is around 0.5, according to Havranek et al. (2015). Although the simulated EIS in this study is not directly estimated from household spending data, the findings align with the broader empirical literature, showing that wealthier households tend to have larger EIS.

3 Backgrounds

3.1 Thailand's Car Tax Rebate Policy Overview

The 2011 flood in Thailand was a major disaster, affecting residential, agricultural, and industrial areas alike. As the largest automobile manufacturing hub in Southeast Asia, Thailand faced significant disruptions in the automotive sector. In response, the Thai government implemented a car tax rebate program aimed at stimulating domestic demand for vehicles. The program had a dual purpose: to prevent the economy from slipping into recession and to bolster domestic demand, thereby supporting local manufacturers.

Under this program, eligible car buyers received a rebate equivalent to the excise tax paid, up to a maximum of 100,000 Baht (approximately 3,000 USD), if household purchased a new car during the policy.[1] Excise tax rates varied by vehicle type, ranging from 3 to 25 percent. Specifically, the tax was 3 percent for two-door pickup trucks, 12 percent for four-door pickup trucks, 17 percent for eco-friendly passenger cars, and 25 percent for small passenger cars.

The program opened for enrollment between October 2011 and December 31, 2012. Due to overwhelming demand, manufacturers, despite operating at full capacity, could not fulfill all orders by the end of 2012. However, participants who secured car reservations by the deadline remained eligible for the rebates, with vehicle deliveries and tax reimbursements extending into 2014.

The program's scale far exceeded government expectations. Over 1.25 million Thais enrolled

[1] Eligibility was restricted to vehicles manufactured in Thailand, priced below 1 million baht, with passenger car engines not exceeding 1,500 cc, although any size pickup truck qualified.

Figure 1: Thailand's gross domestic expenditure, private consumption expenditure, and car purchases in 2000-2015

(a) Growth trend

(b) Level and linear projection

Source: Data from the Office of the National Economic and Social Development Council

between September 2011 and December 2012, leading to 1.1 million vehicles being purchased and taxes reimbursed by the program's conclusion. Auto sales hit record highs in 2012 and 2013 (Figure 1a), and the economy rebounded with a 7.3 percent growth in 2012, up from 0.8 percent in 2011 (Figure 1b).

Initially promoted as "The First Car Program" to make vehicles more affordable for first-time owners, the program's "first-time" criterion was lax in practice. Car purchases are often household decisions, and many participants were effectively not first-time buyers but used the names of household members or extended family to apply for the rebate. Additionally, the large trade-in volume during and after the policy period, as evidenced by plummeting resale values (Chaithongsri, 2013), suggests that many buyers were upgrading rather than purchasing their first vehicle.

The car sales data suggest that future demand was pulled forward during the program, resulting in the cannibalization of subsequent new car sales. A simple linear projection in car sales indicates that an additional 600,000 cars and trucks, out of 1.1 million vehicles, were purchased by advancing future demand (Figure 1b).

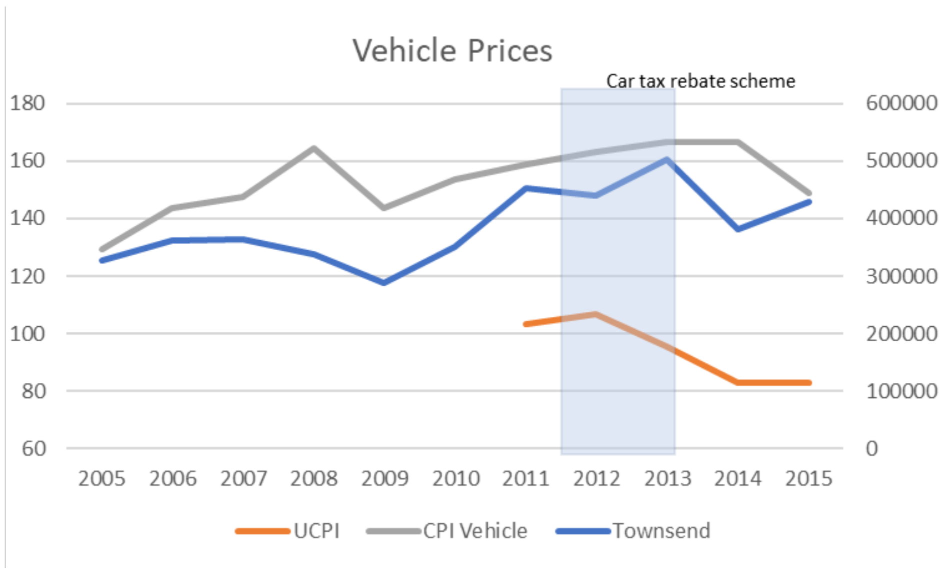
From a fiscal perspective, the program adversely impacted the government's budget balance. The decline in car sales following the scheme resulted in lost tax revenue, while ongoing tax rebates imposed an additional budgetary strain. According to a study by the Thai Parliamentary Budget Office, the government lost approximately 20 to 30 billion baht in tax revenue due to this scheme

(TDRI, 2014).

3.2 Expectations, Car Prices, and Resale Markets

The flood disaster and the car tax rebate program were completely unexpected. The government had not mentioned the program during their election, making the excise tax rebate during this period entirely unforeseen.

Figure 2: Personal vehicle price indexes



Source: The Bank of Thailand; Bureau of Trade and Economic Indices; and author's calculation from Townsend's Thai Data: Urban and Rural Resurvey

The program had significant general equilibrium effects. Used car prices fell during and after the program due to the influx of used cars into the market. A survey of the resale market indicates that the policy exerted downward pressure on used car prices (Chaithongsri, 2013).

To track the second-hand market, the Bank of Thailand introduced a used car price index (UCPI) starting in 2011. Figure 2 illustrates trends in car prices using the Consumer Price Index (CPI) for personal vehicles, the Bank of Thailand's UCPI (left axis), and household expenditure on car purchases from Townsend Thai Data (right axis). The data shows that used car prices began to decline during the policy and reached a low in 2014, approximately 25 percent below their peak in 2012. Similarly, the vehicle CPI, which reflects new car prices, also dropped in 2015, two years following the policy.

The average values of vehicles recently acquired by households from 2005 to 2015, based on Townsend Thai Data (Figure 2). This includes expenditures on both new and used cars. Prior to and during the policy, average spending per vehicle closely followed the Consumer Price Index for vehicles (CPI-vehicle), indicating that household spending was aligned with vehicle prices. However, after the policy, household spending on durable vehicles dropped sharply and aligned with the Used Car Price Index (UCPI). This shift suggests that while pre-policy spending was consistent with the CPI-vehicle, the significant decline in resale prices post-policy also led to a greater share of used car purchases. However, in 2015, the new car prices dropped to compete with used car prices and household spending per vehicle bounced back again due to the drop in new car prices.

In summary, the aggregate data indicates that Thailand's car tax rebate significantly influenced household consumption and car purchases decisions. The policy substantially increased domestic spending, with notable boosts across all expenditure categories during the policy period.

However, domestic demand remained subdued in the subsequent years, with recovery in private consumption primarily driven by increased spending in the service sector from foreign tourists, rather than domestic sources. To isolate the policy's effects from other influencing factors, such as a potential recession or low income due to a sluggish global economy, a structural approach is necessary to evaluate the policy's impact. The next section will present a life-cycle consumption and saving model incorporating cars as a luxury durable goods into the model. Moreover, the policy's impact on used car prices will motivate an experiment that incorporates used-car markets into household decisions.

3.3 Consumption tax, income tax, and rates of returns

In addition to the car tax rebate, I conducted policy experiments involving a VAT reduction, an income tax cut, and interest rate hikes.

Thailand's VAT has been set at 7 percent without an increase for a long time. The income tax system is progressive, with rates starting at 10 percent for those earning more than 300,000 baht per year and rising to 35 percent. However, as shown in Table 6, the median income in 2005 was only 100,640 baht, meaning most Thais did not have pay to pay income tax during the policy. More recent data indicates that approximately 1 in 6 Thais, or one-third of the labor force, are in the formal sector and file taxes. Of these, only 40 percent actually pay income tax, amounting to 4 million people per year, which represents only 6 percent of the population (Muthitacharoen et al., 2019).

However, the key purpose of the income tax cut experiment in this study is that the benefit is proportional to household income rather than to wealth or consumption. Therefore, in the Thai context, this experiment is more realistic if viewed as a 5 percent tax cut for formal taxpayers and a cash transfer proportional to existing income for lower-income households who do not pay taxes and those in the informal sector. Policy-wise, Thailand occasionally implements ad hoc income tax exemptions as a stimulus, and there are existing cash transfer programs such as the ”State Welfare Card for the Poor.”

Finally, I also examined the effects of interest rate hikes on welfare, savings, and household spending. In 2011, savings interest rates were 3.25 percent, T-bill or government bond yields were around 3.9-4.2 percent, and state-enterprise bonds ranged from 7 to 25 percent. For the experiment, I set the return rate of (liquid) assets at 5 percent.

3.4 Thai Households Data

This paper utilizes household panel data from Townsend Thai Data, Urban and Rural Resurvey from 2005 to 2015. This dataset includes details information on income, consumption, liquid and illiquid assets, and household characteristics for both urban and rural areas. The data is employed to estimate household income processes and utility parameters.

A limitation of the Townsend Thai data is that it does not fully represent the entire country, though it is representative of the sampled provinces. I, therefore, use Townsend data only to estimate parameters. Then to ensure that the aggregate result is representative of Thai households, weights from the Survey of Socioeconomic Status (SES), stratified by age and education. Additionally, comparison of summary statistics (Table 1) between Townsend Thai Data and the Socioeconomic Survey (SES)—the primary household data collected by the National Statistical Office—indicates that the Townsend Urban and Rural Resurvey data together closely approximate the average in the SES sample. For example, the average gross income and the number of vehicles owned in SES fall between the averages observed in Townsend's urban and rural data. Additionally, the proportion of college graduates reported in SES data aligns with the figures from Townsend's urban and rural areas.

Table 2 presents summary statistics and the composition of household assets. In the model, household assets, denoted as A, include both liquid and illiquid assets. Liquid assets encompass savings, checking accounts, and cash. Illiquid assets cover a range of items, including household fixed assets, vehicles other than cars or pick-up trucks, land, land with housing, agricultural assets, business assets, lending, and net liabilities.

Table 1: Summary Statistics of Thai Household Demographics in 2009-2010

Year/Data set	**SES**	**Townsend Urban**	**Townsend Rural**
Variables	2009	2010	2010
Male	0.67	0.56	0.64
	(0.47)	(0.50)	(0.48)
Age	51.7	54.87	55.99
	(14.65)	(11.39)	(12.40)
College	0.11	0.17	0.04
	(0.32)	(0.38)	(0.19)
Gross Income (THB)	250,832	286,993	194,827
	(427,440)	(323,263)	(247,116)
Number of household members	NA	4.08	3.89
		(1.91)	(1.78)
Saving	NA	45,031	36,362
		(280,436)	(154,095)
Number of passenger cars owned	0.12	0.17	0.06
	(0.39)	(0.43)	(0.26)
Number of pick-up trucks owned	0.25	0.25	0.24
	(0.51)	(0.48)	(0.48)
Number of cars and pick-up trucks owned	0.37	0.42	0.30
	(0.65)	(0.64)	(0.57)

Standard errors in parenthesis
**Weighted average and standard errors adjusted*
Source: SES and Townsend Thai Data Annual Resurvey

Excluding illiquid wealth would significantly misrepresent household asset holdings. With an average liquid asset holding of 27,000 THB, which constitutes only 6% of the average household net wealth of 436,000 THB (Table 2), it is crucial to include illiquid assets for an accurate depiction of household wealth. While the model assumes costless access to illiquid wealth, this may be overly optimistic for higher-frequency analyses, such as monthly or quarterly responses.

Analysis of household wealth composition shows substantial inequality in Thailand. The average wealth far exceeds the median, with most households lacking ownership of land, housing, or vehicles. Over half of households do not own a car, and the average value of household vehicles is 63,000 THB, which is about 15% of the average net wealth (Table 2).

3.4.1 Income

Individuals with primary to secondary education level are often in the informal sector, or work in a low-skilled or minimum wage jobs in the formal sector. Therefore, they have very flat income profile over the life-cycle. Meanwhile, those with higher education at tertiary level, including post-

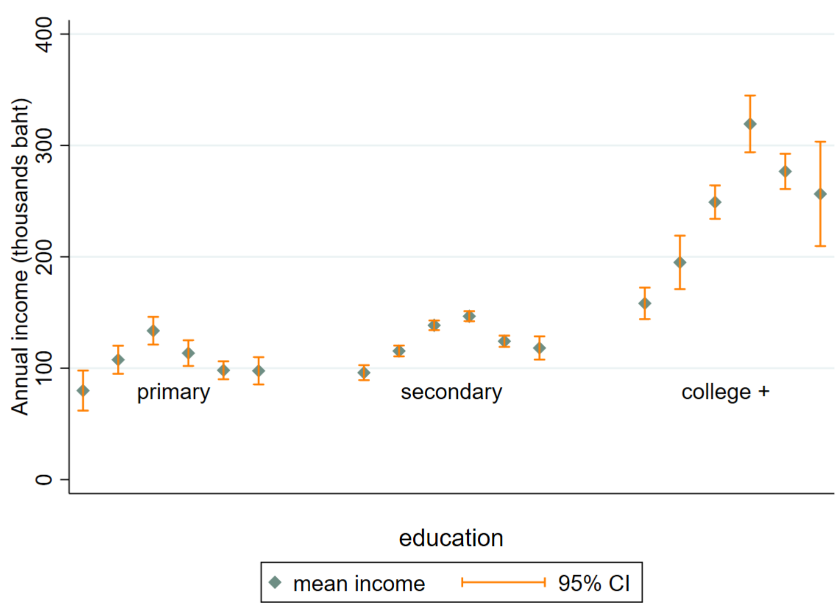
Table 2: Thai Household Asset Portfolio Composition in 2005

	Mean (2002THB)	Mean Fraction of wealth	Median (2002THB)	Median Fraction of wealth
Income	163,153	0.37	100,640	0.92
Net wealth	436,012		109,195	
Net Liquid asset	27,322	0.06	3,660	0.03
Illiquid assets net liability	408,690	0.94	95,952	0.88
Household fixed asset	112,200	0.26	27,905	0.26
Vehicles	63,650	0.15	0	0.00
Land	400,974	0.92	0	0.00
Land with housing	42,990	0.10	0	0.00
Agricultural assets	11,096	0.03	0	0.00
Business assets	15,824	0.04	0	0.00
Borrowing	134,499	0.31	39,524	0.36
Lending	3,095	0.00	0	0.01

Source: Townsend Thai Data Annual Resurvey, 2005

high school certificates or college degrees will be in a mid- or high- skill jobs, and have relatively steeper income profile over the life-cycle.

Figure 3: Income of households by age and education



Plots shows mean income of age groups [26-35),[36,45),...[76,85] for each education levels respectively.
Source: Townsend's Thai Data, Annual Survey year 2005-2011

Figure 3 shows the differences of life-cycle income profiles between these groups. Households with primary and secondary education exhibit similar average income profiles, with the secondary education group showing lower standard errors due to a larger sample size. Meanwhile, households with tertiary education or higher demonstrate significantly higher income levels and a more pronounced hump-shaped income profile over the life cycle. The income growth for households with primary or lower education remains relatively flat across ages. Notably, workers in the informal sector, typically those with lower education, do not have a formal retirement age and often cease working as they age, relying on family support. In comparison, formal sector workers, generally more educated, tend to retire between the ages of 60 and 65.

To model these income profiles, I estimate age polynomials up to the fourth degree to capture the age-dependent income trends. The residuals from these year and age income regressions are subsequently used to estimate the parameters of an AR(1) process, with separate estimations conducted for two education levels: primary/secondary education and tertiary education or higher.

4 Model

Households allocate their consumption between two types of goods: non-durables and durables. They accumulate risk-free assets and durable goods, and can borrow within specified constraints. Durable goods fulfill a dual role, offering a stream of services and serving as a store of wealth.

For the purpose of evaluating Thailand's car tax rebate policy, durable goods in this study are limited to household personal vehicles, including both passenger cars and pick-up trucks (referred to as "cars" for brevity). While durable goods in other contexts might encompass a broader range of assets such as housing and various personal items, this study specifically focuses on cars due to their relevance to the car tax rebate policy.

The adjustment costs of cars in the model encompass relevant costs of car resales, such as search costs, psychic costs, registration fees, and losses due to asymmetric information. In the absence of adjustment costs, households would optimally adjust their cars every period, and all car owners would have participated in the car tax rebate policy if they have sufficient assets or credits.

4.1 Household Optimization Problem

Households live for 60 periods, $j = 1, ..., 60$, representing ages from 26 to 85. Household ages are proxied by the ages of household heads in the data. They consume two types of goods: non-durable goods, C_{it}, and a stream of services from durable goods, D_{it}, in each period while receiving exogenous stochastic income, Y_{it}. They also store their wealth in two assets: a risk-free asset with no adjustment costs, A_{it}, and durable goods, D_{it}. Household i maximizes the expected utility function

$$E_t[\Sigma_{j=1}^{J}\beta^j U(C_{i,t+j}, D_{i,t+j}) + \beta^{J+1}B(W_{it+J+1})],$$

where $B(\cdot)$ is the value of terminal wealth in period 60.

4.1.1 Preferences

In each period, a household consumes two types of goods: non-durable goods and the service flow from durable goods. The stream of service flow is proportional to the size of durables, consistent with the standard assumption in the literature. Cars are considered luxury goods in Thailand. Given that less than fifty percent of households in the survey owned a car, and the likelihood of car ownership increased with income and wealth, cars are modeled as a luxury.[2] The preference for car demand is assumed to be non-homothetic to capture the non-linear Engel curve in car purchase spending.

This study adopts the Cobb-Douglas utility function—as a special case of the CES utility function with an intratemporal substitution elasticity of 1—as a benchmark. This choice is justified by the fact that estimates of elasticity between non-durables and durables in the literature are not statistically different from 1 (Berger and Vavra, 2015). Furthermore, using the Cobb-Douglas utility function aligns with recent literature on household durable goods with adjustment costs (Berger and Vavra, 2015; Fernandez-Villaverde and Krueger, 2011). [3]

Households are assumed to have a per-period Cobb-Douglas utility function as follows:

$$U(C_{it}, D_{it}) = \frac{1}{1-\sigma}(C_{it}^{\alpha}(D_{it}+\tau)^{1-\alpha})^{1-\sigma}$$

In a static setting with standard Cobb-Douglas preferences, deterministic income, and no asset accumulation, the share of demand for durable and non-durable goods is constant for any given level of income. In other words, there is no income effect, and the income expansion path or Engel curve is linear.

Adding the τ parameter to the utility function allows the income expansion path for cars to be non-linear. The optimal consumption share of non-durable to durable goods for households with

[2]Typical alternative modes of transportation include personal motorcycles, public transport, and various forms of taxis such as tricycle, or motorcycle or sedan taxis.

[3]Kaplan and Violante (2014) utilized a different functional form, Epstein-Zin-Weil, to decouple EIS and relative risk aversion in their model of housing demands.

sufficiently low income (or wealth) and large τ will be 1:0. When household asset holdings or income are sufficiently high, the ratio of $C : (D + \tau)$ is equal to $\alpha : (1 - \alpha)$. As income rises, the ratio of C will converge to $\alpha : (1 - \alpha)$. However, in a dynamic setting, the ratio of C could differ, as governed by the first-order conditions for intertemporal and intratemporal marginal utility. [4]

With the Cobb-Douglas utility function specification, the intratemporal substitution parameter is assumed to be equal to 1. However, non-homothetic preferences imply that intratemporal substitution varies among households according to their wealth levels. Low-wealth households have relatively low intratemporal substitution. At sufficiently low wealth, households will optimally choose not to own a car and will not change their durable demand even when facing a large price shock. This implies no intratemporal substitution between demand at that level of income and prices.

4.1.2 Per-period budget constrains, assets and borrowing constraints

The per-period budget constraint without adjustment costs is

$$C_{it} + P_t(D_{it} - (1 - \delta)D_{it-1}) + A_{it} = Y_{it} + (1 + r)A_{it-1}. \tag{1}$$

To accurately capture household wealth, A, the model incorporates both liquid and fixed assets. The majority of household fixed assets are in the form of land and housing (Table 2). For completeness, the asset data also include other broad durables such as electronic devices and furniture. However, the share of wealth contributed by these broad durables remains relatively small. These assets are not subject to adjustment costs and are assumed to be collateralizable, or accessed costlessly within the period of one year.

Additional to the budget constraints, household consumption should be nonzero, and asset level do not go below borrowing constraint:

$$\begin{aligned} C &\geq 0 \\ D &\geq 0 \\ A &\geq \underline{A_j}, \end{aligned}$$

where $\underline{A_j}$ is the borrowing constraint of household age j.

Borrowing or credit constraints are an important friction for the car adjustment as households without sufficient assets or income may or may not be able to purchase a car due to limited access

[4] One could model the stream of durable goods in the utility function by incorporating a scaling parameter to allow the parameter α to better reflect the share between durable and non-durable goods.

to credit. In this study, the borrowing constraints specified are age-dependent and based on the distribution of net assets observed in household data. The borrowing constraints account for the limited credit access, particularly those in the informal sector. These households, due to a lack of regular salary documentation, are less likely to qualify for car loans. While they may have some credit access, they cannot borrow freely beyond their constraints. Some informal richer household would be able to given they have enough assets. This approach better aligns with the credit realities faced by low-income households in Thailand, where access to car loans is more restricted compared to developed economies.[5]

To retain the characteristics of cars as illiquid assets, they are not modeled as collateralizable without liquidation. However, all other fixed assets are assumed to be accessible costlessly , and hence collateralizable, maintaining the distinction of cars as illiquid assets. Future research could explore the potential for cars to be collateralized in a more detailed debt modeling framework. Such an extension would offer further insights into the financial dynamics and borrowing constraints associated with car ownership.

4.1.3 Income Process

Households face an exogenous and stochastic income process. Household i at time t is at age j_{it} and has an income process defined as

$$ln(Y_{it}) = \chi(j_{it}) + \gamma_t + y_{it}$$

throughout the life-cycle: $\chi(j_{it})$ is the deterministic age-dependent parameter (age polynomial up to the 4th degree), γ_t is year fixed effects to capture aggregate income shocks, and y_{it} is the residual income.

The residual income, y_{it}, has two components: the permanent shock z_{it} and the temporary shock ε_{it} . z_{it} is the household permanent shock that follows an $AR(1)$ process as specified below:

[5]Note that regardless of whether there are imposed borrowing constraints, there is a natural borrowing constraint given the utility functional form. Households have $-\infty$ utility if non-durable consumption is zero. This feature of the utility function imposes a natural borrowing constraint—additional to the imposed borrowing constraints $\underline{A}$—on the asset level. Households are heavily penalized when they cannot afford positive non-durable consumption.

$$
\begin{aligned}
y_{it} &= z_{it} + \varepsilon_{it} \\
z_{it} &= \rho z_{it-1} + \mu_{it}, t = 1, ...T \\
\rho &\in [0, 1] \\
\mu_{it} &\in N(0, \alpha_{\mu}) \\
\varepsilon_{it} &\sim N(0, \alpha_{e}) \\
z_0 &\sim N(0, \alpha_0).
\end{aligned}
$$

As discussed earlier, household income processes parameters are estimated separately for different education levels.

4.1.4 Adjustment Costs

Adjustment costs are incurred only if households decide to adjust their durable levels. This study specifies two types of adjustment costs: 1) proportional adjustment costs (F_v) and 2) fixed adjustment costs (F_o). The proportional adjustment cost, F_v, is a transaction cost that is proportional to the value of the cars being sold. It captures the time and psychic costs of selling a car—cars with higher value may require more time and effort to sell—and also possible higher losses in value due to asymmetric information. Note that this cost depends only on the size of the existing durable, not on the new purchase, which is a standard specification in the literature. This yields a policy rule that depends only on the state variable and not on the choice variable. Moreover, an additional fixed cost, F_o, is included to capture value-invariant costs of selling a car, such as title transfer and license registration fees.

The total adjustment cost given durable holding D_{t-1} is equal to

$$F = F_v P_t D_{t-1} + F_o. \tag{2}$$

Having two types of adjustment cost parameters allows for flexibility in matching moments of adjustment frequency at varying levels of income and wealth. Both types of adjustment costs could produce infrequent adjustment of durable goods. However, the proportional adjustment cost results in a policy function that depends on the size of the state variable D. The proportional adjustment cost enters the first-order condition directly and affects households with varying levels of wealth uniformly. On the other hand, fixed adjustment costs do not enter the first-order condition but have a similar effect to a wealth effect. Fixed adjustment costs create varying degrees of adjustment frequency depending on household wealth levels.

4.1.5 Terminal Value of Wealth

Townsend Thai data reveals that Thai households often retain a significant level of assets even as they approach the end of their lives. This phenomenon may be attributed to the fact that many older individuals continue to reside with their children, extended family, or grandchildren. The observed lack of asset deaccumulation suggests the presence of bequest motives or precautionary saving behaviors. To replicate this empirical observation, households are assigned a terminal wealth value function.

For simplicity, I maintain the structure of the utility function and assigned a scaling parameter, ψ, as the terminal wealth value function:

$$V_T = \psi \frac{\left[(A_T)^{\alpha}(D_T + \tau)^{1-\alpha}\right]^{1-\sigma}}{1-\sigma}$$

4.1.6 Recursive Form

The household dynamic problem as described above can be written in a recursive form. Let $s \equiv (A, D, z, j)$ represent the state variables, where A denotes household wealth, D represents durable holdings, z permanent income shock, and j indicates age. In each period, households must decide how much to spend on non-durable, save and whether or not to adjust their durable stocks. This discrete decision is made by comparing the optimal value of each possible adjustment scenario.

Households face different budget constraints depending on whether they choose to adjust their durable holdings. In each sub-problem, they also face different per-period budget constraints and nonzero consumption constraints.

The value function given the state variables s is

$$V_t(s) = \max\{V_t^{\text{adjust}}(s), V_t^{\text{no adjust}}(s)\}. \tag{3}$$

Households solve the following dynamic problem if they adjust their durable holdings: For $t = 1, \ldots, 60$:

$$
\begin{aligned}
V_t^{adjust}(s) &= \max_{C,A',D'} U(C,D') + \beta E[V_{t+1}(s')|z] \\
\textit{s.t.} \quad A' + PD'(1+tax_d) + C(1+tax_c) &= (1+r)A + y(z)(1-tax_y) + (1-F_v)(1-\delta)PD - F_o \\
A' &\geq \underline{A}_{t+1} \\
D' &\geq 0 \\
C &\geq 0 \\
s' &= (A', D', z', j+1).
\end{aligned}
$$

where tax_d, tax_c, and tax_y are the (effective) tax rates on cars, non-durable goods, and income. If households adjust their durable consumption, they determine two choice variables, A' (next period assets) and D' (durables), while C must comply with the per-period budget and the nonzero consumption constraints.

Households solve the following sub-problem if they do not adjust their durable holdings:

$$
\begin{aligned}
V^{no\ adjust}(s) &= \max_{C,A'} U(C,D) + \beta E[V(s')|z] \\
\textit{s.t.} \quad A' + C(1+tax_c) &= (1+r)A + y(z)(1-tax_y) - \delta PD \\
A' &\geq \underline{A}_{t+1} \\
C &\geq 0 \\
s' &= (A', (1-\delta)D, z', j+1).
\end{aligned}
$$

In this case, they have only one choice variable, A', while C must comply with the budget and nonzero consumption constraints.

Given the two value functions $V^{\text{adjust}}(s)$ and $V^{\text{no adjust}}(s)$ for the the state variable s, households decide whether to adjust their durable stocks or not by comparing the value of each option and choosing the one with higher value.

4.1.7 Resale Prices

To incorporate the resale markets into the model in the alternative policy experiments on car tax rebate, households will face the following budget constraints instead. If they do not adjust their durable they face the budget constraint:

$$
A' + C(1+tax_c) = (1+r)A + y(z)(1-tax_y) - \delta PU^* D,
$$

where PU is the resale prices. If they adjust their durables they face the budget constraint:

$$
A' + QD'(1+tax_d) + C(1+tax_c) = (1+r)A + y(z)(1-tax_y) + (1-F_v)(1-\delta)PU^* D - F_o,
$$

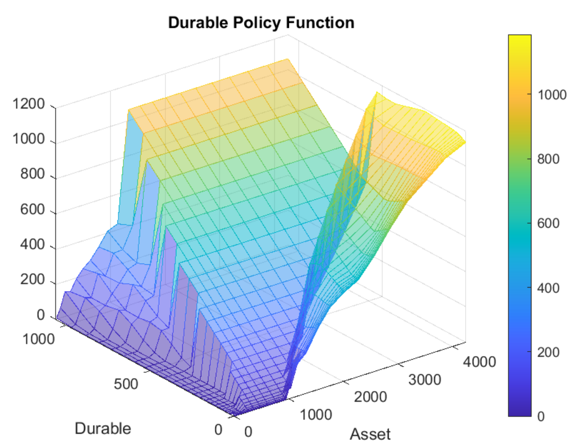
where Q is the two-tier prices of new and used cars:

$$Q = \begin{cases} P & \text{if } D' \geq 500,000 \\ PU & \text{if } D' < 500,000. \end{cases}$$

4.2 Model Solutions

The model is solved backwards numerically from the terminal period. In each period, households solve two sub-problems: the adjust and non-adjust cases. They will make adjustment decisions based on the value functions of the two sub-problems choosing the option with higher value. (See Appendix A.2 for details)

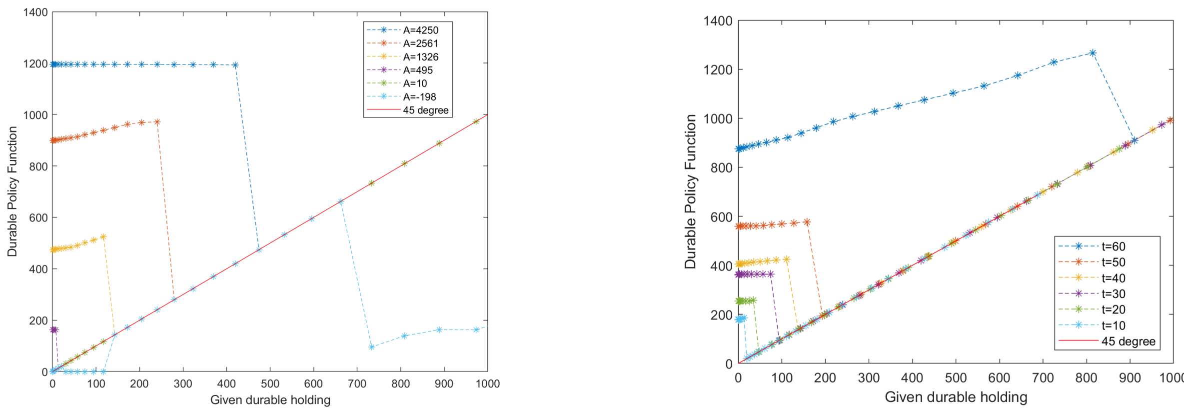
Figure 4: Policy function of durable holding given A and D



The model solutions resemble the (S,s) bands optimal rule. To aid in visualizing the solution, it is helpful to consider the solution to the problem without adjustment costs as a benchmark. If households could adjust their stock of cars without incurring costs, they would re-optimize their durable levels every period according to the two first-order conditions and constraints. For a given set of state variables, there exists an optimal level of durable goods, $D(A, D, j, z)$, and assets, $A'(A, D, j, z)$, that solves the problem V^{adjust} when adjustment costs are zero. Introducing positive adjustment costs essentially creates an inaction band around this optimal point, (A', D). The larger the adjustment costs, the wider the inaction band.

An example of a policy function for the state space (A, D) is illustrated in Figure 4. The flat plane represents the inaction region where it is optimal for households to maintain their current level of durable goods. The right corner indicates the region where their current durable level

Figure 5: Durable Policy Function



(a) durable policy function at different levels of asset for households age 55 and $z = 0$

(b) durable policy function for households at different ages, $A = 200,000$ and $(z = 0)$.

becomes too low, and household will adjust the D' upward. In contrast, the left corner shows the region where households will adjust their durable stock downward, typically when asset levels are too low, leading them to sell cars as a buffer stock.

As wealth increases, the demand for durable goods rises. The higher the wealth, the greater the lower-bound threshold of the inaction band. Figure 5a Households near the borrowing constraint at $A = -198$ will sell most durable goods unless levels are too low to cover fixed costs. If assets are low but above the constraint at $A = 10$, households typically maintain their current durable goods without adjustment. Figure 5b illustrates durable demand across different ages, showing a policy function level set for assets of 200,000 baht and a zero permanent shock. The demand for durable goods increases with age, reflecting that older households have less incentive for precautionary savings and are closer to the end of their life cycle. As households age, their focus shifts more toward current consumption, leading to higher durable demand.

Another key parameter influencing the size of durable purchases is the adjustment cost. When adjustment costs are high, households are incentivized to purchase larger stocks of durables to avoid frequent adjustments and the associated costs. This behavior reflects the trade-off between the cost of adjusting durable goods and the benefits of maintaining an optimal stock, with higher costs leading to less frequent but larger purchases.

4.3 Model Mechanisms

Shocks in income or prices influence household behavior through three primary channels: 1) the income channel, 2) the substitution or price channel, and 3) the wealth or consumption smoothing channel. This section examines the impact of changes in model parameters on consumption and saving behaviors, focusing on the dynamics of each channel.

4.3.1 Income Channel

Price shocks can influence demand through the income channel, as real income changes as a result of price changes. When real income rises due to a price drop, the demand for both durable and non-durable goods typically increases. In a standard Cobb-Douglas utility framework, this increase would occur proportionally, as demand aligns with income shares. However, the introduction of a non-homothetic parameter distort this proportional income effects.

In the presence of non-homothetic preferences and adjustment costs, real income must rise significantly to overcome these frictions and induce an increase in car demand. Conversely, because non-durable consumption and saving face no such adjustment costs, their demand will increase more readily with rising real income.

4.3.2 Substitution or Price Channel

When relative prices change, households adjust their consumption by shifting towards cheaper goods or investing in more affordable assets in the case of asset prices. The parameter α controls the demand shares for each type of good, with the elasticity of substitution (ES) between goods being 1 in a standard Cobb-Douglas utility function (i.e., $\tau = 0$). However, when τ is nonzero, ES varies with household wealth or income.

A higher τ value results in a larger consumption share of non-durable goods, meaning households with low income (wealth) might have zero demand for durable goods. For these households, small changes in the relative prices of durable goods will not affect their nondurable demand or vice versa, leading to zero ES.

4.3.3 Wealth or Consumption Smoothing Channel

When asset prices, such as interest rates and car prices, change, they can impact household behavior through the wealth effects channel. An increase in interest rates can enhance household wealth and the marginal utility of saving. Older households might increase consumption due to their increased wealth, while younger households may save more, driven by a stronger precautionary saving motive. Additionally, higher real interest rates could result in fewer car purchases as returns on alternative assets become more attractive. Car prices and resale values also influence household wealth, impacting household consumption and saving decision through this channel.

5 Empirical Strategy

5.1 Estimation

This section outlines the data and estimation strategy. Some parameters are selected from external data or related studies, while the income process parameters are estimated exogenously to match reported income in the household panel data. With these predefined and income process parameters, the remaining parameters are estimated within the model using the Generalized Method of Moments (GMM), matching simulated data moments to household data moments.

Parameters fixed outside the model include r, δ, F_o, and β. Parameters estimated within the model include $\tau_{c\in\{1,2,3\}}, \alpha, \sigma$, and ψ. Parameters τ are allowed to vary by cohorts: 26 to 45 years old, 46 to 65 years, and 66 to 85 years old. The variation in τ by cohort reflects differing preferences for cars, which are influenced by the perceived necessity of cars at different life stages and also the fact that learning to drive and the accessibility of cars are different for each cohort. The parameters estimated within the model are also separately estimated for two education level groups.

I chose to estimate key parameters that are unique to the model specification, while other more common parameters are chosen from outside evidence or related literature. While initial data are set equal to household data in 2005 as described the following section. The moments are targeted at $Agegroup \times \times Year \times Edu$ cells. Parameters are estimated to match data prior to the car tax rebate in year 2006 to 2011.

5.2 Household Data

To estimate the model parameters, data moments are constructed from the Townsend Thai Data, which includes the Urban and Rural Resurvey. This dataset provides a detailed and continuous panel of household assets, consumption, and income over more than a decade, making it the most comprehensive panel of Thai household-level data available. Simulated data are initialized based on the 2005 household data, considering state variables, including age, assets, income level, and

Table 3: Distribution of Thai Household Income and Assets in 2005

Percentile	Young	Middle Age	Old
Income			
10th	20.3742	21.2512	12.5640
30th	45.9021	49.9741	34.8406
50th	79.9840	82.0556	60.3843
70th	117.2353	135.2242	113.9034
90th	216.1224	252.5160	239.1180
Asset			
10th	-83.2559	-100.6770	-57.9023
30th	-25.3541	-31.0156	-4.9154
50th	-5.5769	-1.7940	23.0558
70th	27.6121	65.4760	151.1958
90th	410.2276	475.8174	798.6896
Personal Vehicles			
10th	0	0	0
30th	0	0	0
50th	0	0	0
70th	0	0	0
90th	197.6870	256.1757	198.6870

Value in real term in year 2002 thousand THB
Source: Townsend Thai Data Annual Resurvey, 2005

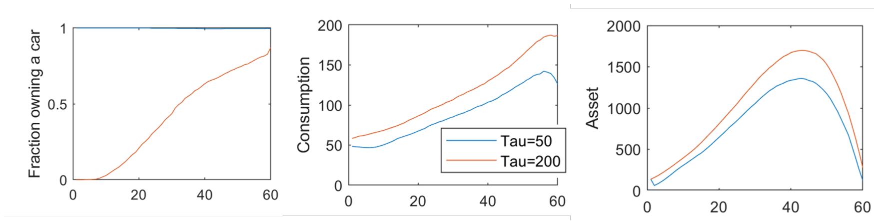
durable holdings. Table 3 presents the initial distribution of income, assets, and car ownership by household age groups.

The details on asset data construction is included in Appendix A.1. Household non-durable consumption includes spending on food, alcoholic beverages, tobacco, gasoline (excluding business or farm use), and ceremonies. It also encompasses expenditures on services and semi-durable goods such as house and vehicle repairs, education-related expenses, clothing, and food eaten away from home. To account for economies of scale in consumption for larger households, the OECD equivalence scale is applied.

5.3 Identification

Given previously estimated income process parameters, the next step is to search for key parameters that generate simulated moments that match data moments. To estimate the model effectively, I fix certain parameters while allowing others to be estimated because some parameters co-govern household consumption and saving decisions, the choices of which parameters to estimate is to prioritize pinning down related moments. For example, similar studies, such as Kaplan and Vi-

Figure 6: Comparative statics of life cycle profiles by non-homothetic parameter (τ)



olante (2014) and Berger et al. (2018) estimate the discount rate, β, and choose the common value of σ equal to 2 in the literature. I choose to fix β and estimate σ in this study to focus on estimating spending responses, and saving profiles.

Specifically, I estimate the curvature parameter (σ), the non-homothetic parameter (τ), the proportional adjustment cost (F_v), nondurable-share α, the curvature parameter σ, and and the terminal wealth parameter (ψ). Meanwhile, the fixed adjustment cost (F_o) is based on external evidence, and the discount rate (β) is fixed at 0.95.

Key moments used to match the data include household asset levels, non-durable and durable spending, and the fraction of households owning cars within each Age Group $\times$ Year $\times$ Education cell. The decision to aggregate data moments by year for each sub-age group, rather than relying solely on age profiles, and to incorporate year fixed effects into the income process, is intended to prioritize accurate predictions of aggregate spending in each year across different sub-age groups while accounting for macroeconomic conditions.

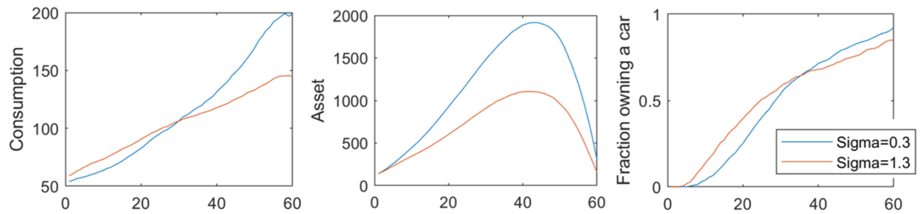
While parameters such as τ, σ, and α influence both consumption and saving behaviors simultaneously, certain moments are more closely associated with specific parameters. For instance, the fraction of car ownership is essential for identifying the non-homothetic parameter τ. Given a particular τ, nondurable spending levels help to pin down α. Differences in consumption and saving profiles over the life cycle inform the curvature parameter σ, while durable purchase sizes are also determined by adjustment costs, F_v.

I provide comparative statics and more detailed discussion of how key parameters, including τ, σ, and F_v, shape household consumption and saving profiles below.

Non-homothetic Parameter: When cars are considered a necessity with few substitutes in the form of non-durable goods or services, i.e., low τ, nearly everyone owns a car Conversely, if cars are a luxury goods, individuals are more likely to delay car purchases until they have accumulated sufficient assets, leading to lower ownership rates earlier in life (Figure 6, left panel).

However, purchasing cars early in life leads to lower asset accumulation and non-durable con-

Figure 7: Comparative statics of life cycle profiles by curvature parameter (σ)



sumption later on. As a result, younger households are less likely to own cars when τ is high, waiting until they are older and wealthier to make such purchases. Car ownership also increases monotonically over the life cycle for any value of τ.

To better capture generational differences in car ownership and preferences, I allow τ to vary by cohort, reflecting the fact that younger households might have different preferences or necessities than older households. Specifically, τ_1 denotes non-homothetic parameter for households aged 25 to 44 in 2005, τ_2 for those aged 45 to 64, and τ_3 for those aged 65 to 85, allowing for more flexible ownership patterns across generations.

Curvature parameter:[6] Households with high σ or low elasticity of intertemporal substitution (EIS) prefer smoother, or flatter, consumption over their life cycle (Figure 7). Households with low σ (high EIS) tend to delay consumption when young, choosing to save more and consume at higher levels in later life.

In the presence of durable goods, this behavior extends to smoothing durable consumption. Households with high σ (low EIS) prefer purchasing durable goods earlier in the life-cycle to maintain steady durable consumption over the lifetime. This also leads to lower savings and reduced consumption of both durable and non-durable goods later in life.

Adjustment costs Adjustment costs are also key variables that determine the size of household durable purchases, or frequency of adjustment. If the adjustment costs are high, household will be more likely to make a large purchase to avoid frequent adjustment, while if the adjustment costs are low, they will make adjustment frequently to stay near the optimal durable level as governed by first order conditions.

Therefore, a household's decision of car ownership and its values over the life cycle is determined by F_o, F_v, and τ, but also σ. F_v will enter the first order condition and affect durable spend-

[6]Given a standard constant relative risk aversion (CRRA) utility function, σ is the coefficient of relative risk aversion, and EIS is equal to $1/\sigma$. However, given the non-homotheticity in durable good preferences, σ is no longer equivalent to the coefficient of relative risk aversion, and $1/\sigma$ is no longer the EIS. Nonetheless, the inverse relationship between relative risk aversion and EIS remains. For clarity, the parameter σ will be referred to as the curvature parameter.

ing proportionally for all values of durable spending, while F_o and τ will move together to match the level of optimal durable spending. Therefore, in order to estimate τ, I fixed F_o at 8 matching typical transaction costs of purchasing a car.

6 Results

6.1 Income

To estimate household income process parameters, first I fitted the household income with year fixed effects and age polynomial variables separately by household education levels. The AR(1) process parameters then are estimated using GMM by matching the covariance matrix of the residues to the covariance matrix generated from the AR(1). The estimates are shown in Table 4. Figure 8 shows fitted income profiles by the model compared to the data for the overall sample. As expected, household income follows a typical hump-shaped pattern, peaking around age 60.

Figure 8: Fitted income profile and data

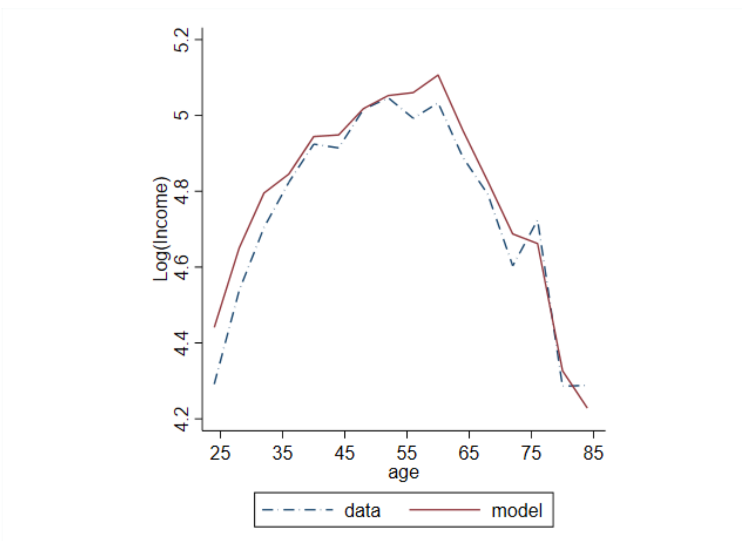


Table 4: Income parameters by education level

Education level	ρ	σ_u	σ_ϵ	σ_{zo}
Primary and secondary	0.955	0.062	0.373	0.334
Tertiary and higher	0.99	0.024	0.205	0.431

6.2 Model Fits

Estimation results are reported in Table 5. Non-homotheticity parameters (τ) are lower for younger cohorts compared to older ones, consistent with data showing that car usage is more prevalent among younger households. Additionally, τ is lower for the tertiary education group, indicating that cars are less of a luxury for this group relative to primary or secondary education households.

Table 5: Parameter Estimates by education level

Education level	$\tau_{a\in[26,44]}$	$\tau_{a\in[46,65]}$	$\tau_{a\in[66,85]}$	α	σ	ψ	F_v
Primary or secondary	1032.5	1226.5	1432.8	0.27	5.01	3.59	0.1498
Tertiary	300	531.89	1029.4	0.43	2.53	4.09	0.1461

The parameter α, representing the share of nondurable consumption in a standard Cobb-Douglas utility function, is 0.27 for the primary/secondary education group and 0.43 for the higher education group.[7]

The curvature parameter (σ) is estimated at 5.01 for lower education households and 2.53 for higher education groups. This suggests that households with higher education may experience a steeper consumption profile than those with lower education. This finding aligns with the fact that higher-education households generally exhibit greater income growth over time, leading to steeper consumption patterns. Finally, the proportional adjustment cost parameter (F_v) is estimated to be approximately 0.14 for both education groups.

Figures 9 and 10 present comparisons between model-generated and data moments. The inclusion of terminal value parameters and cohort-specific parameters results in a strong match between the model and data for both asset levels and car ownership rates across all age groups. While the model-generated moments for durable spending fit the data reasonably well, non-durable spending tends to be underfit for younger cohorts.

6.3 Policy Experiments

To evaluate the redistribution effects of various policy instruments, I conduct four policy experiment exercises: car tax rebate, consumption tax cut, proportional income tax cut, and interest rate hikes. These policies operate through different channels: price effects, income effects, and wealth effects.

[7]This value is smaller than nondurable share observed in the data due to the non-homotheticity specification. α moves along with τ.

Figure 9: Targeted Moments: Assets and Fractions of Car Owners

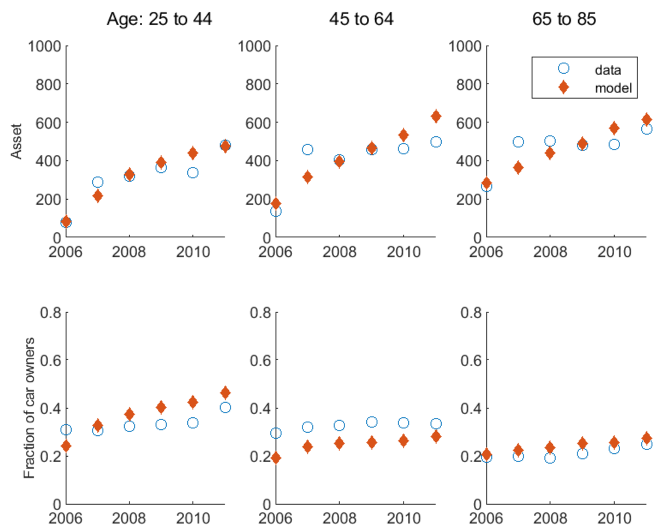
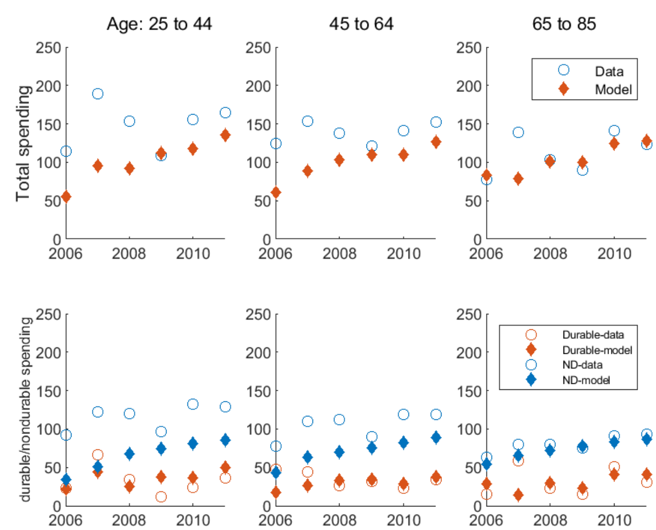


Figure 10: Targeted Moments: Durable and non-durable spending



First, car tax rebate: This policy affects all three channels. The price reduction leads to both price (or substitution) effects and an increase in real income. Additionally, it influences household wealth by affecting the stock of illiquid assets. Second, consumption tax cut: This policy primarily operates through price channels, resulting in both substitution and income effects. Third, proportional income tax rebate: This policy operates solely through the income channel, without influencing prices. Last, interest rate hikes: This policy impacts households only through wealth effects, as it affects their spending power based on existing assets.

To simulate the Thai economy, households are simulated with an initial distribution of income, assets, personal vehicles and age from Townsend Thai data in 2005. In particular, I use initial distribution of income, assets and cars representative of households in each quintile and cohort.Then Thailand's population distribution by age is used to weigh the sample to be representative of the cohort distribution in the economy. I choose the age of 26, 46 and 66 as the initial age to represent young (26 to 45), middle age (46 to 65), and old (66 to 85) cohort respectively (Table 6).

Table 6: Ratio of Thai household by age and education levels

Education/ age	25 to 44	45 to 64	65 to 85	sum
Primary or secondary	0.27	0.44	0.15	**0.83**
Tertiary	0.07	0.06	0.01	**0.14**

Source: Thai Socio-economic Survey data, 2010

6.3.1 Car tax rebate

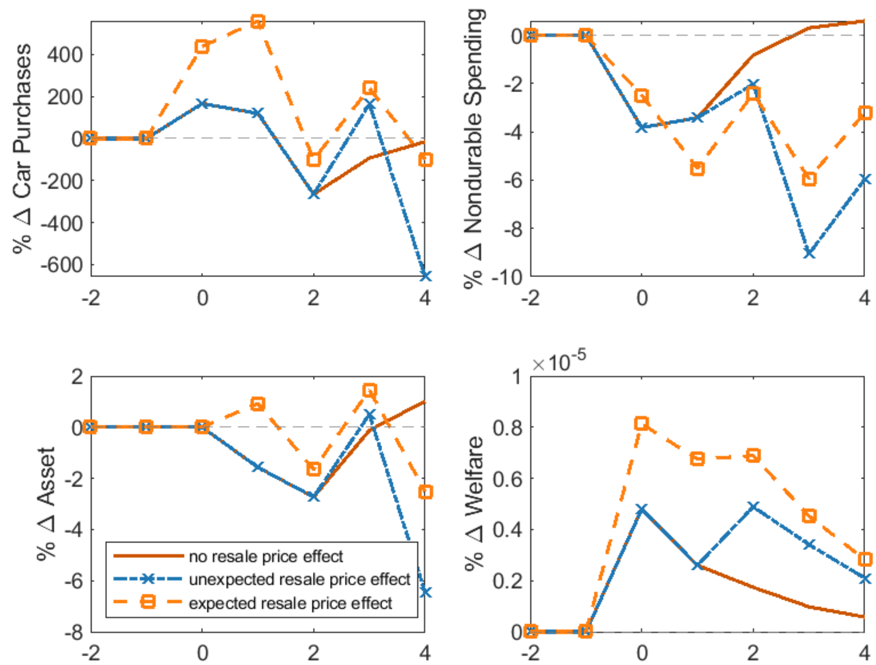
The car tax rebate policy introduces a temporary, unanticipated, and favorable shock to car prices. In the simulation, this policy experiment is implemented unexpectedly introducing a tax break that lasts for two years, corresponding to event times $t = 0$ and 1. To reflect the policy's stipulation that tax rebates apply only to new car purchases, I imposed a rule that partially restricts households to benefit from the tax break only if their purchase exceeds 500,000 THB during the policy. If they purchase cars value less than this during the policy, they will not receive the car tax rebate.

The simulation also replicates the policy regulation requiring households to return the tax rebate if they sell the claimed vehicles before the end of five years of ownership. To do this, households will face a fixed cost of excise tax values at the time of purchase if they sell their cars during the 5-year period post-policy.

Resale market: As discussed in Section 3), used car prices dropped as much as 20 percent after the policy ended, and gradually returning to near pre-policy levels over the next five years. To account for these fluctuations, I conducted additional policy experiments incorporating a two-tier pricing system: new car prices and used car prices. Households will purchase cars valued below the entry-level new car price, 500,000 baht, at used-car prices. Moreover, when adjusting their car holdings, households will sell cars in the resale market at used-car prices. With this two-tier pricing structure, households will optimize their choice between new and used cars, selecting the larger durable option for the price they are willing to pay. [8]

[8]This simplification excludes luxury car purchases in the resale market, which represent a very small share in Thai-

Figure 11: Percent changes in aggregate car purchases, non-durable spending, savings, and lifetime utility from the three car tax rebate policy experiments



Price expectations: Households' expectations of resale prices also significantly influence their behavior. In the second policy experiment, I assume that households realize the drop in resale prices only after the policy ends, at $t = 2$. The third experiment assumes that households have perfect foresight and correctly expect the post-policy resale prices right from the policy's announcement.

These three policy experiments are designed to capture different scenarios:

- **Policy Experiment 1:** No changes in car prices or resale prices, except for the tax exemptions during the policy.
- **Policy Experiment 2:** Changes in resale prices, with households realizing the drop in used car prices after the 2-year policy period ends.
- **Policy Experiment 3:** Changes in resale prices, with households having perfect foresight and anticipating this from the policy's announcement.

land.

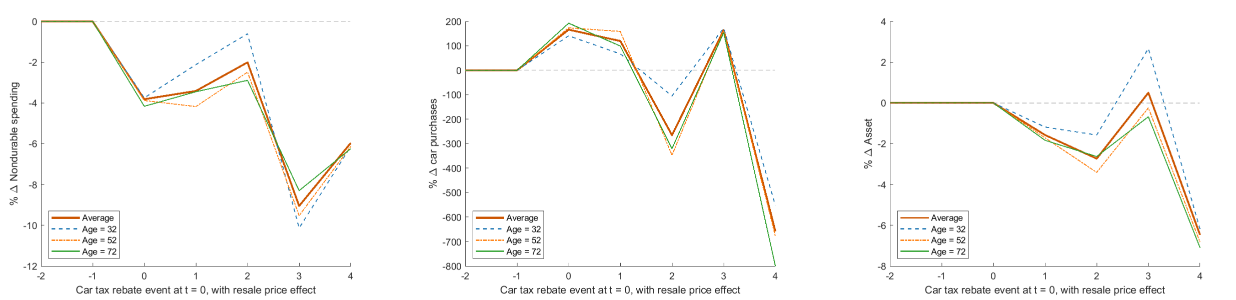
Figure 11 illustrates the percentage changes in car purchases, non-durable spending, savings, and gains in lifetime utility (value function) across the three policy experiments, compared to a counterfactual baseline scenario without the car tax rebate program. Overall, the results consistently show that the policy significantly stimulated car purchases during its implementation, but this came at the expense of reduced non-durable consumption and savings both during and after the policy period.

When factoring in the drop in used car prices, the post-policy purchases of used cars further boosted overall spending on vehicles.[9] However, the model predicts that this second spike in used car purchases would lead to an even greater reduction in household assets or savings, with savings declining more than in the scenario without changes in used car prices.

In the third policy experiment, where households had perfect foresight of the drop in used car values, the model predicts even higher durable spending during the policy. This behavior can be attributed to households anticipating the decline in resale values and therefore choosing to buy cars during the policy period, rather than adjusting their car stocks later and facing lower resale prices.

For the breakdown of policy impacts on spending, saving and welfare, I will present the results from Policy Experiment 2, as it more accurately reflects the observed increase in durable spending during the policy period while also accounting for the effects of resale prices.

Figure 12: Effects of car tax rebate experiment by household age



(a) Non-durable spending (b) Car purchases (c) Asset

Note: Results from Policy Experiment 2 with unexpected changes in resale prices, showing percent changes in aggregate car purchases, non-durable spending, and savings compared to the baseline of no car tax rebate

Policy prediction shows that older households increase their car purchases the most during the policy whereas younger household increase their car purchases the least (Figure 12). This aligns

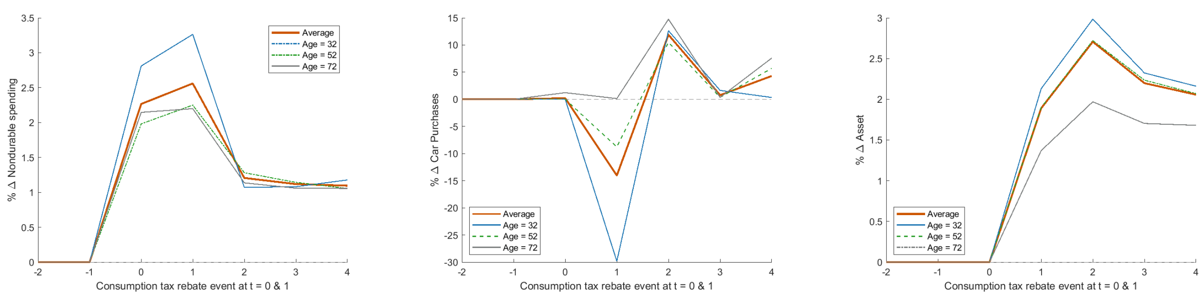
[9]It is important to note that this post-policy increase in car purchases would not directly contribute to GDP, except through the markup services associated with selling used cars.

with the lower saving incentives and also greater wealth or spending power of older households. The second spike in car purchases post-policy mainly reflects lower-income households entering the resale market. Having been unable to afford new cars during the policy, they could purchase used car at lower prices post policy. The drop in resale prices results in even deeper reductions in non-durable spending and savings, further prolonging the negative effects. Younger households, in particular, increased their participation in car purchases during the resale price decline.

6.3.2 Consumption tax cut

Another common fiscal stimulus is a consumption tax cut. In Thailand, consumption tax exemptions are sometimes introduced on an ad hoc basis, typically after the New Year, to stimulate domestic spending. To compare the effects of a consumption tax cut with the car tax rebate within the same period, this experiment tests the impact of exempting the 7 percent consumption tax during event times $t = 0$ and 1.

Figure 13: Effects of consumption tax cut experiment by household age



(a) Non-durable spending (b) Asset (c) Asset

Note: showing percent changes in aggregate car purchases, non-durable spending, and savings resulting from consumption tax cut policy

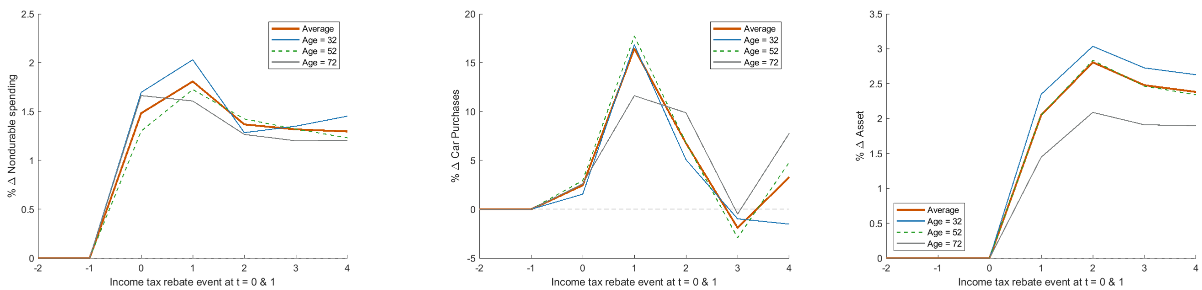
Given the 7 percent consumption tax exemption, households increase non-durable spending by 2.5 percent on average (see Figure 13). The consumption tax cut also generates substantial substitution effects, resulting in an average reduction of nearly 15 percent in car purchases during the policy. Despite this, car purchases during the post-policy period are higher than the baseline. Overall, spending in the economy increased by over 2 percent during the policy period. Unlike the car tax rebate policy, this tax cut also leads to a 2.5 percent increase in overall savings.

When comparing by household age, young households increase both their consumption and savings, while reducing their car purchases the most.

6.3.3 Cash transfer or proportional income tax cut

In contrast to the previous exercises involving car excise tax and consumption tax exemptions, which operated through both price and income channels, this exercise isolates the income channel by assuming a proportional 5 percent income tax reduction for all households. This approach aims to illustrate household responses and welfare gains resulting solely from an income increase, without the influence of price changes.

Figure 14: Effects of proportional income tax cut experiment by household age



(a) Non-durable spending (b) Car purchases (c) Asset

Note: showing percent changes in aggregate car purchases, non-durable spending, and savings resulting from proportional cash transfer or income tax cut by 5 percent

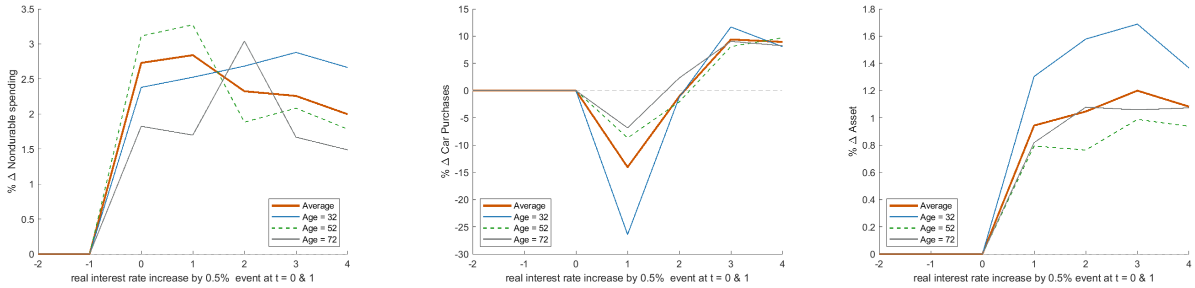
For the purpose of policy experiment, I test the impact of additional windfall of 5 percent income across all households. As anticipated, without the influence of price changes, income tax cuts do not reduce spending in any categories. A 5 percent income tax reduction leads to an average increase of 1.8 percent in non-durable spending, a 17 percent increase in car purchases, and a 2.7 percent rise in savings. Older households see the smallest increases in spending and savings, reflecting their generally lower income levels in this age group.

6.3.4 Interest rate hikes

This exercise explores how households respond to changes in interest rates. Unlike the previous exercises that involved price and/or income channels, this one affects households solely through the wealth channel. Interest rate increases enhance returns on savings or liquid assets, and also making durables or illiquid assets relatively less attractive.

In contrast to the income tax cut, which affects household behavior through both price and income channels, interest rate hikes influence household decisions primarily through wealth channels. Higher interest rates make cars relatively more expensive to own compared to higher-return

Figure 15: Effects of interest rate hikes by household age



(a) Non-durable spending (b) Car purchases (c) Asset

Note: Percent changes in aggregate car purchases, non-durable spending, savings, and life-time utility due to a 10 percent increase in interest rate (from 5 percent to 5.5 percent).

savings, leading to reduced car purchases during the policy period. However, post-policy, car purchases exceed baseline levels as households benefit from increased wealth accumulated during the rate hikes.

The rise in interest rates also results in positive wealth effects, boosting both non-durable spending and savings overall. Young households experience the most significant increase in savings due to the enhanced saving incentives provided by higher interest rates.

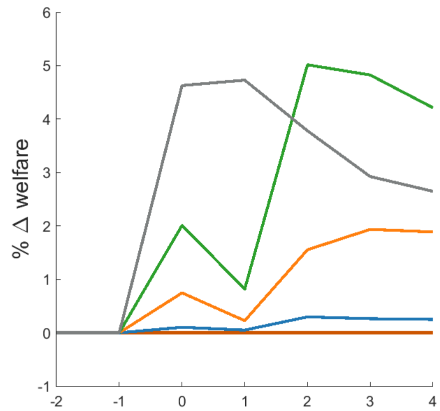
6.4 Welfare analysis

This section compares the redistribution impact of the four policy experiments by analyzing welfare gains across income quintiles.[10] Note that the welfare gains presented here are calculated based on household lifetime utility. As such, the gains are influenced by the form of the utility function and its curvature. Higher percentage gains in welfare typically reflect greater marginal utility improvements, which are more pronounced for households with lower baseline consumption.

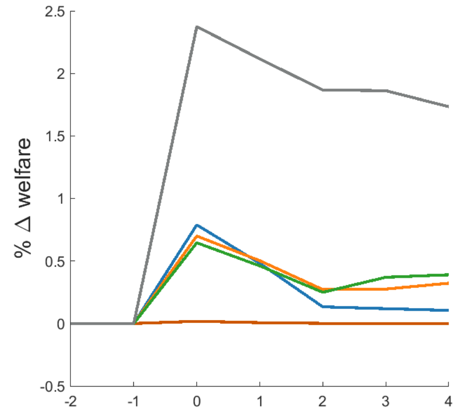
In the first two policy experiments— car tax rebate (Figure 16a) and consumption tax cuts (Figure 16b)— which operate mainly through price channels, households are influenced by substitution, income effects, and, in the case of the car tax rebate, also wealth effects. Households in the top quintiles benefited the most from these policies due to their higher baseline consumption of both durables and nondurable goods. Conversely, households in the bottom quintile experienced the least benefit.

[10]Income quintiles are defined based on the income distribution within each age group, rather than by the overall income distribution.

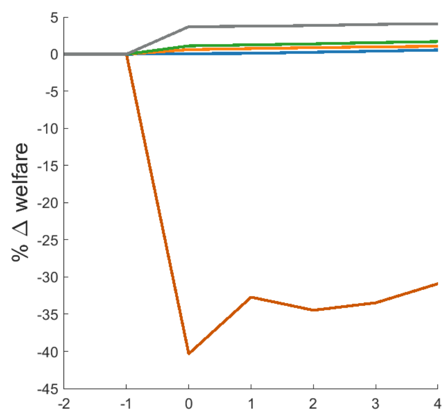
Figure 16: Welfare redistribution by household income quintiles



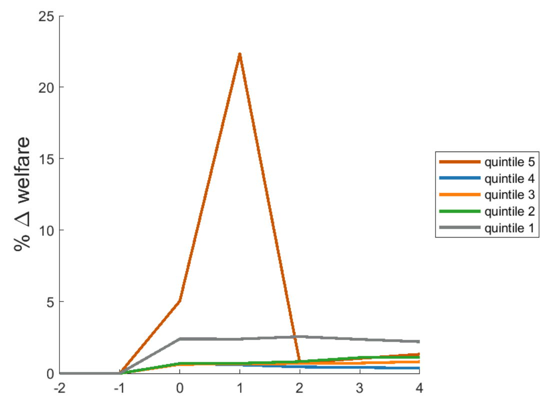
(a) Car tax rebate



(b) Consumption tax rebate



(c) interest rate hike



(d) Proportional income tax rebate

Note that this welfare changes are based on lifetime utility values. Therefore, the size is subjected to the utility functional form.

In contrast, income tax cuts, which operate solely through the income channel, and interest rate hikes, which impact households exclusively through the wealth channel, yield different welfare impacts. In these exercises, the bottom quintile experienced the largest gains from the income transfer, given their low baseline consumption (Figure 16d). However, they also faced the most significant welfare losses during interest rate hikes due to their higher levels of debt or negative savings (Figure 16c). On the other hand, interest rate hikes and income tax cuts disproportionately benefited the top quintile, as this group holds the largest income and wealth.

6.5 Elasticity of intertemporal substitution

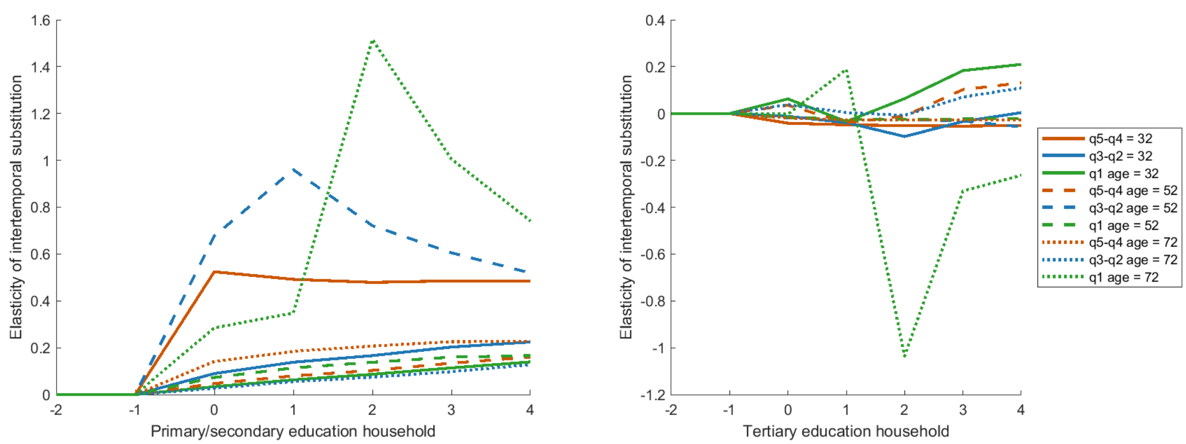
Table 7: Spending and savings responses to interest rate hikes

	t				
	0	1	2	3	4
Nondurable	2.73	2.84	2.32	2.26	2.00
Car purchases	0.00	-13.28	-1.32	9.84	9.46
Total spending	2.57	2.04	1.77	3.12	2.82
Asset	0.00	0.94	1.05	1.20	1.08

Percent change in non-durable spending, car purchases, total spending and asset given unexpected rate increase of 10percent (from 5 percent to 5.5 percent) during event t = 0 and 1.

In this section, I calculated simulated EIS given the shock in interest rate hikes of 10 percent, increasing from 5 percent to 5.5 percent during the event time $t = 0$ and 1 from policy exercise in Section 6.3.4. The rate hikes of 10 percents leads to 2 percent increase in total spending, and 0.94 percent in asset. The aggregate implied EIS is 0.25, positive and small (see Table 7). However, when stratified by income, age, and education, there is a large heterogeneity EIS by houshold income, wealth and age.

Figure 17: Simulated EIS by household education, age and income level



EIS calculated by dividing the percent changes in cumulative spending from $t = 0$ up to $t = t$ by the size of the 10 percent interest rate hike.

Some households show positive EIS, that is they increase non-durable spending when the interest rate increases. This is likely because the wealth effect from the rate hike is stronger than marginal utility of additional saving. Most have EIS around 0 to 0.2, aligned with the aggregate EIS rate, increasing their spending modestly given the interest rate increases.

However, some lower-income households exhibit a more pronounced response to interest rate changes (Figure 17). For instance, young households with primary to secondary education and low income show an EIS of approximately 0.6, while middle-income households aged 52 have an EIS of around 1 at $t = 0$, immediately following the interest rate increase. In contrast, high-income households aged 72 experience their EIS peak at 1.4 during $t = 2$, one period after the policy, likely due to increased wealth effects from the rate hike.

Certain households, particularly low-income and younger individuals with higher education (age 32, income quintiles 4-5), respond to interest rate hikes by decreasing their spending. This suggests their strong saving motives. In contrast, high-income households aged 72 show an increase in spending during rate hikes and a decrease when rates drop. This suggests a strong positive wealth effect from the rate changes, as these households benefit more from higher returns and have low precautionary saving needs due to their accumulated wealth.

In summary, the simulated EIS is positive on average. However, poorer and younger households exhibit negative EIS due to precautionary saving motives and possibly negative wealth effects. Wealthier and older households, on the other hand, display more positive and intratemporal responses to interest rate changes, driven by lower precautionary saving needs and significant wealth effects.

7 Discussion

This section discusses the results, limitations, and potential extensions for future research.

The paper utilizes a partial equilibrium model to simulate household consumption and saving behavior, treating durable goods as luxury items with adjustment costs. While this allows for a richer and more numerically intensive household optimization problem, it does not capture the general equilibrium effects the policy may have on the car resale market. To address the policy's price impact on the second-hand car market, I introduced two-tier pricing for new and used cars, refining the policy predictions by incorporating the used car market into the household model. The findings suggest that the policy made used cars more affordable for low-income households but also led to larger and more persistent reductions in savings and non-durable spending.

Younger household spending in the model is undershoot in comparison to data. To address this issue, future research could explore a few adjustments to utility function or borrowing constraints. This might involve allowing them to borrow more or tailoring constraints to more specific household characteristics, potentially improving the model's fit. I also assumed Cobb-Douglas utility function, as used in Fernandez-Villaverde and Krueger (2011). While this functional form aligns with the standard approach in the literature and with intratemporal substitution estimates between non-durables and durables (Ogaki and Reinhart, 1998), future research could explore relaxing this assumption to capture potentially different intratemporal substitution patterns between durable and non-durable goods.

Next, the current borrowing constraints are set with age-specific limits based on household asset data, which reasonably reflect the borrowing capabilities of Thai households during the policy period. In Thailand, many individuals are employed in the informal sector and lack regular documented salaries, which limits their access to car loans. Conversely, those who do have access to car loans typically possess either sufficient assets for collateral or stable incomes that qualify them for such loans. However, future studies could also investigate the role of cars as collateral or explore default risks associated with car ownership. This would be particularly relevant for exploring household debts and financial stability in greater detail, especially given the recent trend of small financial institutions giving out more car loans to households in the informal sector over the past few years.

Lastly, studies on life-cycle model usually assume a common value of 2 for the relative risk aversion parameter (Aaronson et al., 2012). Similar study on durable consumption, such as Berger et al. (2018) and Fernandez-Villaverde and Krueger (2011), also assumed the value to 2 while estimating the discount rate. However, in order to focus on match spending responses, this paper adopts a different approach by estimating curvature parameters while assuming a discount rate value. The estimated risk aversion is 5 for low-education households and 2.6 for high-education households, which closely aligns with these recent and related studies. Recent work, such as Parodi (2024), has also estimated the risk aversion parameter to be 3.72, whereas McKay and Wieland (2021), in their study of durables and consumption responses to monetary policy shocks, set it at 4 to align with empirical evidence. The simulated aggregate EIS in this paper is 0.25, also consistent with the EIS assumed in McKay and Wieland (2021).

8 Conclusion

Policy simulations reveal that older households significantly increase their car purchases during tax rebate periods, whereas younger households show a more modest increase. The surge in new car purchases leads to a substantial drop in used car prices, which in turn triggers a second wave of second-hand car purchases among lower-income households. This prolongs the negative effects on non-durable spending and savings and also makes these effects more widespread, highlighting a potential decrease in tax revenues from VAT and car excise taxes post-policy, and reduced saving or investment in other types of assets.

This paper also examines the impact of alternative policy instruments, including consumption tax cut, proportional income cash transfer, and interest rate hikes, to illustrate how different policy tools affect households through various channels. In term of stimulus efficiency, car tax rebates provide the strongest short-term stimulus by influencing household behavior through all three, price, income, and wealth, channels. Consumption tax cuts are the second most effective stimulus, with a reduced negative impact on future savings in the absence of wealth effects. Proportional-income cash transfers offer a lower immediate stimulus but avoid long-term negative effects cannibalizing future consumption and savings. It also boosts future consumption persistently working through income channels. Interest rate hikes increase spending among households with savings but may lower contemporaneous spending of those with debts or strong precautionary saving motives. This results also highlight substantial heterogeneity in the EIS across households of different ages and wealth levels.

In conclusion, to balance fiscal sustainability with redistribution, policies should be designed with progressivity in mind. Targeted policies such as cash transfers to the poorest households offer significant welfare improvement for low-income households. Conversely, programs like luxury durable tax rebates, while highly effective as a stimulus, disproportionately benefit the top quintiles, leading to less equitable outcomes and potentially jeopardizing fiscal sustainability. Meanwhile, broad-based policies, such as raising economy-wide interest rates or implementing income tax cuts, can have highly heterogeneous impacts across households. Without a careful policy designs, they can be regressive, affecting the most vulnerable negatively and benefited the already well-off the most. Specific measures targeted at particular groups could help mitigate these adverse consequences.

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A Appendix

A.1 Fixed asset data

Townsend data reports the initial asset value in the first survey, and all the new purchases of fixed assets in the following resurvey. To construct a household fixed asset profile, I use depreciation rates specific to particular types of fixed assets. Household board durables, including appliances, are assumed to depreciate at rate 16.5 percent, agricultural assets at 13.15 percent, and business assets at rate 15.79 percent. The rates are chosen based on the depreciation rates used by the U.S. Bureau of Economic Analysis on the most related board durables in each category. Fixed asset value and household car value are calculated following the standard law of motion:

$$d_{it} = (1 - \delta_d)d_{it-1} + I_{it}$$

where d_{it} is the fixed asset or car value in each period and I_{it} is the new purchase of the fixed asset at time t. For the purpose of the car tax rebate policy evaluation, only passenger cars and pick-up trucks are included in the value of durable consumption, D_{it}, in the model. Other types of fixed assets are included in household wealth, A_{it}. The depreciation rate for cars is assumed to be 9.4 percent.[11]

A.2 Computation note

A.2.1 Computation

The model is solved backwards numerically from the terminal period. In each period, households solve two sub-problems: the adjust and non-adjust cases. They will make adjustment decisions based on the value functions of the two sub-problems choosing the option with higher value.

In the non-adjust case, households continue to consume at the existing levels of durables, adjusted for depreciation from the previous period. At a given level of durables and assets, the next period's asset level and nondurable consumption are chosen to optimize the problem according to the intertemporal first-order condition for interior solutions. Corner solutions may arise if borrowing constraints are binding or if consumption is zero.

[11] According to the author's calculation to fit the aggregate capital stock and gross capital investment of personal vehicles in the private sector as reported by the Capital Stock of Thailand and National Income (NESDB, 2017)

In the adjust case, households have two choice variables: durable and nondurable consumption. These variables are determined by the two first-order conditions governing intratemporal and intertemporal substitution. Corner solutions may occur due to binding borrowing constraints or positive consumption levels.

To compute the policy function and value function, I solved the model backwards from the terminal period. The state space for durable goods and assets is discretized to 30 grids each: $a_1, a_2, ..., a_{30} \times d_1, d_2, ...d_{30}$. The value of the maximum and minimum grids in each period of the life cycle is based on the range of asset and durable holdings at each age from Townsend Thai data. The permanent shocks are also discretized into 9 states using the Tauchen method. The policy function is then evaluated at each state variable on the grids, although the solutions are not restricted to the same grids. Due to the highly discontinuous nature of the value function, I solve the dynamic problem by using a brute-force grid search. Details on the steps to solve the model are as follows:

1. The terminal period assets are constrained to be non-negative. The last period solution is solved given the terminal period function of wealth.

2. Given the state variables, the non-adjust problem in period 60 is solved by searching over next period asset values. First, the cash on hand available, given that the household will not adjust durable level, is computed. The cash on hand is then discretized into fine grids and the solutions are searched over the grids. Nondurable consumption is computed according to a per-period budget constraint and is constrained to a nonzero value. The grid representing the next period's asset levels is constructed so that nondurable consumption is nonzero. If the implied consumption is negative given the cash on hand, a big negative value is assigned to the value function. A larger negative value is assigned to a more negative asset. The solution is the grid that yields the highest value.

3. A similar procedure is followed for the adjust case. However, now there are two variables to search over: the levels of adjusted durable goods and the levels of assets. To solve for the adjust case the cash on hand, given that existing durable goods are sold, is calculated. The cash on hand then is discretized into fine grids to search over the next period asset level. For each grid of the next period asset level, a set of fine grids of possible adjusted durables is constructed, given that consumption level must be positive. The level of consumption is computed by the per-period budget constraint. The solution is the grid that yields the highest

value.

4. For each set of state variables, the value functions between the two cases are compared to decide whether households will adjust the durable levels. Value function for $t = 60$ is stored.

5. Solve the model for $t = 59$, following the same procedure. The new set of grids of state variables are calculated according to data. The values of continued value function over the fine grids that are searched are calculated using linear interpolation.

6. Repeat the process for $t = 58, ..., 1$ following the same procedure.

Extrapolation: To allow for solution in t to fall outside the maximum value of the already specified grids in $t + 1$, extra grids with very large values of asset and durable levels are added and solved for to allow for the solution in $t + 1$ to be extrapolated. Solutions that fall outside the grids specified for period $t + 1$ are estimated by using linear interpolation to the value at the extra grids.

The algorithm is vectorized to maximize computation efficiency. The total time to solve the model for one set of parameters is approximately five minutes using Matlab. To estimate model parameters, the program is set up for parallel computing to search over parameters. The program uses Matlab software over supercomputing facility (HPC) provided by Research Computing, Arizona State University. It takes approximately 2 days to estimate one set of parameters.

A.2.2 Survey of Computation Methods

This appendix offers a survey of model solution computation techniques from relevant studies. This includes Fernandez-Villaverde and Krueger (2011), Kaplan and Violante (2014), Berger and Vavra (2015), Berger et al. (2018), and Druedahl and Jørgensen (2017). These papers consider a class of household consumption and saving models with two assets: liquid and illiquid. Transaction costs in accessing or adjusting the illiquid account are present. Two-asset models are shown to match household consumption decisions significantly better than the standard one-asset model. This class of model, however, is computationally expensive to solve and the fact that these models only appear later in the literature is owing to computational advances. Computational techniques used in relevant studies to solve their models are briefly summarized in the table below.

Table 8: Review of Computation Methods of Dynamic Models with Two Assets and Adjustment Costs

Author	**Within-Period Solution**	**Value function calculation**
Fernandez-Villaverde and Krueger (2011)	Search on grid of durables, and perform Quasi-Newton search on asset holding conditional on durable. If close to borrowing constraints, use bisection method.	Approximation: Linear or bilinear interpolation
Kaplan and Violante (2014)	Convert solution into indirect utility form, and derive FOCs and Envelope's conditions to solve for Euler's equation. Solve problem in two stages: 1) total expenditure for each period, and 2) within-period nondurables vs. service flow of durables	Direct calculation using Envelope's conditions and other FOCs.
Berger and Vavra (2015) and Berger et al. (2018)	Search two-dimensional solution using Nelder-Meade algorithm, starting from 3 different values to prevent finding local maximum	Approximation with multi-linear functions in continuous idiosyncratic states and one continuous aggregate state.
Druedahl and Jørgensen (2017)	*Endogenous grid method*	Direct calculation: Envelope's conditions.