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Three Essays in Applied Economics

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Abstract

This dissertation consists of three essays on the theory of interest rate via the overlapping generation model, developmental economics, and behavioral response to taxation. The first essay aims to investigate how a shift in income from young age to old age would change the equilibrium path for the economy. The second essay explores and estimates the connections between international remittances and the level of household poverty in Vietnam using the Vietnamese Household living Standard Survey from 2004 to 2016. In the third essay, we conduct the first meta-analysis of the literature estimating tax elasticity of border sales.

In the first chapter, the model of Banerjee and Pingle (2023) is extended here in the same way Gale (1973) extended the Samuelson (1958) model. Rather than all income being earned in young age, the allocation of labor time is parameterized, so a fraction of labor allocated to young age versus old age can be varied. We find that shifting income from young age to old age does not impact the path of capital, which implies it does not affect the paths for output, the real wage, the capital rental rate nor real interest rate. The shift does decrease saving and decrease the share of saving allocated to the bubble asset. The steady state utility level of consumers is maximized when all income is earned in young age.

In the second chapter, I investigate the relationship between international remittances and poverty in Vietnamese households. Utilizing the Vietnamese Households Living Standard Surveys from 2004 to 2016, our probit models

indicate that international remittances reduce the likelihood of a household being in poverty by 11 to 14 percentage points. Furthermore, using instrumental variables, a bivariate analysis estimates confirm that the impact on poverty reduction is more pronounced for remittances originating from oversea compared to domestic remittances. This finding holds significant implications for policymakers, providing insights into the effective use of remittances and foreign labor migration as strategies to alleviate poverty in Vietnam.

In the third essay, we conduct the first meta-analysis of the literature estimating tax elasticity of border sales. When nearby regions have different tax rates, residents may travel to shop in the lower tax rate region. The extent of this activity is captured by the tax elasticity of border sales (TEBS). We collect 749 estimates of TEBS reported in 60 studies, and conduct the first meta-analysis of this literature. We show that the literature is prone to selective reporting: positive estimates are systematically discarded. Sales of food, retail and fuel are more elastic compared to sales of tobacco and other individual `sin' products. Cross-border shopping is more prominent in the US - compared to Europe and other countries.

Dedication

To my beloved parents, Papa Bình and Mama Lộc, and brother Nghĩa, who have always supported and sacrificed so much to ensure that I have the best opportunity to succeed, and to my loving wife, Ngân, and my son, Ethan, who have believed and encouraged me throughout this journey, this dissertation is dedicated to you with my deepest appreciation and love.

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Thank God for guiding me through all the difficulties. "Rejoice always, pray without ceasing, give thanks in all circumstances" – 1 Thessalonian 5:16-18.

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1.1 Abstract

The model of Banerjee and Pingle (2023) is extended here in the same way Gale (1973) extended the Samuelson (1958) model. Rather than all income being earned in young age, the allocation of labor time is parameterized, so a fraction of labor allocated to young age versus old age can be varied. We find that shifting income from young age to old age does not impact the path of capital, which implies it does not affect the paths for output, the real wage, the capital rental rate nor real interest rate. The shift does decrease saving and decrease the share of saving allocated to the bubble asset. The steady state utility level of consumers is maximized when all income is earned in young age.

1.2 Introduction

Irving Fisher is the economist recognized for beginning a careful discussion of interest rate determination. In his book, *The Theory of Interest as Determined by Impatience to Spend Income and Opportunity to Invest It* (1930), Fisher argues that interest rates are determined by both the degree to which people want to spend now versus in the future, and by investment opportunities.

Samuelson's (1958) introduction of the overlapping generations model is important because it represents the first general equilibrium model of interest rate determination. Previous models, including Fisher's thinking, did not directly link the microeconomic choices of savers and borrowers to a market for saving. Samuelson shows that the rate of population growth fundamentally affects the interest rate, something that Fisher did not consider. Samuelson refers to this as the “biological theory of interest.”

Gale (1973) directly recognizes the importance of using the overlapping generations model for interest rate theory. This is because the extent to which a person earns income and the extent to which a person saves varies over a lifetime. In the simplest Samuelson (1958) model, people earn income and save in their young age, and earn no income and consume out of their saving in their old age. Gale extends the Samuelson (1958) model so that the person earns income both in young age and old age. This leads Gales to two cases. The “Classical case” occurs if people consume more than their income when young. The “Samuelson case” occurs if people consume less than their income when young. Importantly, Gale shows that the inefficiency identified by Samuelson can only occur in the Samuelson case, and the Samuelson case can only occur when the person has a low enough level of old age income.

While Samuelson has only examined the interest rate in pure consumption economy, Diamond (1965) introduces production into the overlapping generation model. The extension allows wages to be determined in the model and people are also able to earn income in old age via interest earning from lending.

Diamond teaches us that the interest rate is determined by the productivity of capital in production, or investment opportunity.

Tirole (1985) extends the Diamond (1965) model by allowing the saving of the young to not only flow into capital but also flow into a bubbly asset. While young age saving flowing into capital provides an old age return on saving through the production process, saving flowing into the bubble provides an old age return on saving through a transfer of good from young to old. In contrast to the equilibrium path for the Diamond economy, which is almost surely inefficient, the Tirole economy yields an infinite number of equilibrium paths. The different multiple equilibrium paths are characterized by the initial bubble. One of the equilibrium paths in the Tirole economy is the Diamond path, where the initial bubble is zero and a zero bubble remains. One of the equilibrium paths is the Pareto efficient path for the economy. Between these two, there are an infinite number of equilibrium paths, all of which converge to the inefficient Diamond steady state. The indeterminacy of the Tirole economy is an issue that makes the model less useful than it otherwise would be. The inefficiency present in both the Diamond and Tirole economies is interesting because we expect market economies to produce efficiency if there are no externalities.

Banerjee and Pingle (2023) modify the Tirole (1985) in two ways. First, they allow capital to accumulate rather than being consumed each period after production. They show, under this condition, capital market-clearing does not imply product market clearing unless the interest rate paid on saving is allowed to deviate from the capital rental rate. Second, and more significantly, they introduce a stock market where the ownership of the firm is passed from one generation to the next using nominal stock shares. They show that this extra condition on the general equilibrium eliminates the indeterminacy and inefficiency in the Tirole model. The single equilibrium path for the Banerjee and Pingle economy is Pareto efficient.

In this paper, we extend the Banerjee and Pingle (2023) model in the same way Gale (1973) extended the Samuelson (1958) model. Rather than assuming no income is earned in old age, we parameterize the work allocation of the person so that the income earned young age versus old age can varied. When our parameter $\mu = 1$, we have the Banerjee and Pingle (2023) model, where the consumer only earns income in young age. When our parameter $\mu < 1$, the consumer earns income in young and old age, with more income being earned in young age as μ gets smaller. Our main interest is in learning how a decrease in μ, which implies a shift in income from young age to old age, changes the equilibrium path for the economy.

Our main findings can be summarized as follows. First, the trajectories of capital stock k_t, output y_t, real wage w_t, and capital rental rate r_t are independent of the parameter μ. Second, although neither the interest rate nor capital rental rate is contingent on μ, the paths of saving and its components do depend upon μ. Furthermore, our analysis reveals that the levels of steady state consumption for both young and old age are increasing in μ, implying an increasing trend in the steady state or Golden Rule utility level with respect to μ.

The structure of the paper is organized as follows. Section II introduces the model of a representative consumer who earns income in both young and old age, outlining the basic dynamic equations. The solutions for other key variables and the determination of steady state values are presented in Section II and III, respectively. In Section IV, we examine the system's dynamics as implied by the core state variables. Section V is dedicated to the presentation and analysis of the equilibrium paths for capital, savings, capital backed asset, bubble assets with associated bubble levels, and the trajectories for the interest rate paid on savings and the capital rental rate. Finally, our conclusions are summarized in Section VI.

1.3 The Model

The model consists of two period lived consumers. In period t, there are L_t young aged consumers and L_{t-1} old aged consumers. The population grows at rate n, so $L_t = [1+n]L_{t-1}$.

All consumers are identical. The utility function of the "generation t consumer" is $U = U\left(c_t^y, c_{t+1}^o\right)$, where c_t^y and c_{t+1}^o are the consumer's young age and old age consumption levels. The consumer has one unit of labor to distribute over his or her lifetime. The fraction μ of work time is allocated to young age, meaning $1-\mu$ is allocated to old age. In all previous models, $\mu = 1$ has been assumed. Our interest is in understanding the implications of allowing $0 < \mu < 1$.

In period t, the firm pays the real wage w_t to the workers it employs. Therefore, the generation t consumer's young age labor income is μw_t and young age budget constraint is

(1) $c_t^y + s_t = \mu w_t$,

where s_t is the saving level. The consumer saves by purchasing θ_t units of a capital backed asset and m_t units of a bubble asset. The price of the capital back asset in terms of goods is v_t, while the price of the bubble asset is p_t. This implies, in real terms, the consumer places

(2) $x_t = v_t \theta_t$

units of saving into the capital backed asset, and

(3) $b_t = p_t m_t$

units of saving into the bubble asset. The total real saving level is

(4) $s_t = x_t + b_t$.

The old age consumer receives labor income $[1 - \mu]w_{t+1}$ but also finances consumption with $v_{t+1}\theta_t$ obtained from selling the capital backed asset and $p_{t+1}m_t$ obtained from selling the bubble asset. Thus, the consumer's old age budget constraint is

(5) $c_{t+1}^o = [1 - \mu]w_{t+1} + p_{t+1}m_t + v_{t+1}\theta_t$.

The consumer maximizes the utility $U(c_t^y, c_{t+1}^o)$ subject to the constraints (1)-(5) by choosing the optional levels for s_t, c_t^y, and c_{t+1}^o. Following Diamond (1965), we use the utility function $U(c_t^y, c_{t+1}^o) = Bln(c_t^y) + [1 - B]ln(c_{t+1}^o)$ to obtain particular solutions. In the Appendix, we show the optimal consumption levels for the consumer are $c_t^y = B\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}} w_{t+1}\right]$ and $c_{t+1}^o = \left[\frac{v_{t+1}}{v_t}\right][1-B]\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}} w_{t+1}\right]$, while the optimal savings level is $s_t = \mu w_t - B\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}} w_{t+1}\right]$. For the consumer to hold both the capital backed asset and bubbly asset, the two must earn the same rate of return. That is, defining the gross rate or return on saving as $1 + i_{t+1}$, we must have (and we show in the Appendix that) $1 + i_{t+1} = \frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t}$. Under this equal return condition, the consumer will be indifferent between the two assets, so from the perspective of the consumer the optimal levels of for θ_t, m_t, x_t, and b_t are indeterminate.

The quantity $\mu w_t + \frac{[1-\mu] w_{t+1}}{\frac{v_{t+1}}{v_t}}$ is the generation t consumer life-time income, where the old age income $[1-\mu] w_{t+1}$ is discounted back to the young age time period. In the Diamond (1965), Tirole (1985), and Banerjee and Pingle (2023) economies, where $\mu = 1$, the return earned on savings does not affect the saving level, nor the young age consumption level; it only affects the old age consumption level. However, in our model, when $\mu < 1$, the return on saving impacts the young age present value of the old age income. Consequently, it affects young age consumption, saving, and old age consumption. Specifically, an increase in the gross return $\frac{v_{t+1}}{v_t}$ earned on saving causes an increase in saving, an increase in old age consumption, and a decrease in young age consumption. This effect is amplified as μ gets smaller, meaning a larger share of lifetime income is earned in old age.

For saving to be positive when $0 \le \mu < 1$, the allocation of labor to young age μ cannot be too small. In particular, in the Appendix we show $\mu > \frac{Bw_{t+1}}{\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t + Bw_{t+1}}$ must hold for the consumer to choose $s_t > 0$. In the Diamond (1965), Tirole (1985), and Banerjee and Pingle (2023) economies, where $w_{t+1} = 0$ and $\mu = 1$, this condition always holds. In our more general economy, the saving level increases as μ increases, and we find the saving level will be positive when the parameter μ is in the range

(6) $\frac{Bw_{t+1}}{\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t + Bw_{t+1}} < \mu \le 1.$

We assume condition (6) holds, so that bubbles have opportunities to form.

A single representative firm produces the economy's total period t output Y_t from labor input and capital input K_t according to the production function $Y_t = F(K_t, L_t^d)$. Again, following Diamond (1965), we use the constant returns to scale production function $F(K_t, L_t^d) = AK_t^{\alpha}[L_t^d]^{1-\alpha}$, where $0 < \alpha < 1$. Letting $k_t = K_t/L_t^d$ and $y_t = Y_t/L_t^d$, the intensive form of production function can be written as

(7) $y_t = Ak_t^{\alpha}$.

The market for inputs is competitive, implying the real factor prices are equal to the factor marginal products. We assume capital depreciates at rate δ. Letting r_t denote the real capital rental rate, the gross capital rental rate is $r_t + \delta$. Using the Diamond production function, the producer maximizes the employment capital only if

(8) $r_t + \delta = \alpha A k_t^{\alpha-1}$.

Letting w_t denote the real wage rate,

(9) $w_t = [1-\alpha]Ak_t^{\alpha}$.

The labor market is in equilibrium, labor demand equals labor supply, or $L_t^d = \mu L_t + [1-\mu]L_{t-1}$. We assume labor supply grows at rate n, so $L_t = [1+n]L_{t-1}$. Therefore, in equilibrium $L_t^d = \mu L_t + \left[\frac{1-\mu}{1+n}\right]L_t$, or $L_t^d = \left[\frac{1+\mu n}{1+n}\right]L_t$. This implies $L_{t-1}^d = \left[\frac{1+\mu n}{1+n}\right]L_{t-1}$ and $\frac{L_t^d}{L_{t-1}^d} = \frac{L_t}{L_{t-1}}$. Since $\frac{L_t}{L_{t-1}} = 1+n$, we find $\frac{L_t^d}{L_{t-1}^d} = 1+n$, or $L_t^d = [1+n]L_{t-1}^d$.

Capital accumulates according to $K_{t+1} = I_t + [1-\delta]K_t$, where $\mathrm{I_t}$ is the period t investment level. Dividing by $\mathrm{L_t^d}$ we obtain $\frac{\mathrm{K_{t+1}[1+n]}}{\mathrm{L_t^d[1+n]}} - \frac{[1-\delta]\mathrm{K_t}}{\mathrm{L_t^d}} = \frac{\mathrm{I_t}}{\mathrm{L_t^d}}$, which can be rewritten as $k_{t+1}[1+n] - [1-\delta]k_t = \frac{I_t}{L_t^d}$. Replacing L_t^d using the labor market clearing condition, we find $\mathrm{k_{t+1}}[1+n] - [1-\delta]\mathrm{k_t} = \frac{\mathrm{I_t}}{\left[\frac{1+\mu n}{1+n}\right]\mathrm{L_t}}$. The capital market clears when the supply of real saving flowing into capital, $\mathrm{L_t x_t}$, equals the investment demand, $\mathrm{I_t}$, or when $x_t = \frac{\mathrm{I_t}}{L_t}$. Imposing the equilibrium, we find

(10) $x_t = [1+\mu n]k_{t+1} - \frac{[1-\delta][1+\mu n]}{[1+n]}k_t$.

Following Banerjee and Pingle (2023), we also include a product market clearing condition.[1] Period t output Y_t either finds its way into consumption C_t or investment I_t. Thus, the capital market clears when $Y_t = C_t + I_t$. Dividing by the labor demand level $\mathrm{L_t^d}$ and recognizing period t consumption is $C_t = L_t c_t^y + L_{t-1} c_t^o$, we obtain $\frac{Y_t}{\mathrm{L_t^d}} = \frac{L_t c_t^y}{\mathrm{L_t^d}} + \frac{L_{t-1} c_t^o}{\mathrm{L_t^d}} + \frac{I_t}{\mathrm{L_t^d}}$. Using the labor market clearing condition $L_t^d = \left[\frac{1+\mu n}{1+n}\right] L_t$ and the definition $y_t = Y_t / L_t^d$, we obtain $y_t = \left[\frac{1+\mu n}{1+n}\right] c_t^y + [1+n]\left[\frac{1+\mu n}{1+n}\right] c_t^o + \frac{I_t}{\mathrm{L_t^d}}$. Using $\mathrm{k_{t+1}}[1+n] - [1-\delta]\mathrm{k_t} = \frac{\mathrm{I_t}}{\mathrm{L_t^d}}$ from above, we find

(11) $$y_t = \left[\frac{1+n}{1+\mu n}\right]\left[c_t^y + \left[\frac{1}{1+n}\right] c_t^o\right] + [1+n]k_{t+1} - [1-\delta]k_t.$$

In addition to the real market clearing conditions for the capital market and product market, we impose market clearing conditions for the financial assets. For ownership in the firm, the stock market for the capital backed asset clears when the supply of stock $L_{t-1}\theta_{t-1}$ sold by the old generation in period t equals the demand for stock $L_t\theta_t$ arising from the young generation's desire to save, or when $L_{t-1}\theta_{t-1} = L_t\theta_t$. Applying the labor growth condition, the stock market clearing condition for period t reduces to

(12) $$\theta_{t-1} = [1+n]\theta_t.$$

Similarly, the market for the bubbly asset clears when the supply of the bubbly asset $L_{t-1}m_{t-1}$sold by the old generation in period t equals the demand

[1] Banerjee and Pingle (2023) show that, when capital is allowed to accumulate rather than being consumed, the product market will not generally clear when the capital market clears, and he also shows that the real interest rate should not be restricted to be equal to the marginal product of capital.

for the bubbly asset $L_t m_t$ arising from the young generation's desire to save, or when $L_{t-1}m_{t-1} = L_t m_t$. Again, applying the labor growth condition, the market clearing condition for the bubbly asset in period t reduces to

(13) $m_{t-1} = [1+n]m_t$.

Together, equations (1)-(5) and (7)-(13) determine the paths of the 12 endogenous variables $c_t^y, x_t, b_t, s_t, c_{t+1}^o, y_t, r_t, w_t, k_{t+1}, 1+i_t = \frac{\mathrm{v_{t+1}}}{\mathrm{v_t}} = \frac{\mathrm{p_{t+1}}}{\mathrm{p_t}}, \theta_t, m_t$ given initial conditions k_1, θ_0, and m_0. The initial generation of old age consumers does not receive interest from saving, but it is due the payments to capital and the initial revenue obtained from issuing the initial bubble. Thus, $C_1^o = R_t K_t + B_t$ or in intensive form $c_1^o = [1+n][r_1 k_1 + b_1]$. The variables $n, \delta, s, \alpha\ A,$ and μ are exogeneous and drive the system. We are primarily interested in how the dynamics and equilibria for this system depend upon the parameter μ.

1.4 Model Solutions

The stock market clearing condition (12) places an important restriction on the economy. In the Appendix, we show the stock market clearing condition, together with the other equations describing the economy, imply a basic dynamic equation for the economy that describes the equilibrium path followed by the model's core variable, the capital stock variable k_t. In particular, we find the basic dynamic equation for our model is

(14) $k_{t+1} = \left[\frac{\alpha A}{1+n}\right] k_t^\alpha + \left[\frac{1-\delta}{1+n}\right] k_t$.

Using equation (14), we further find in the Appendix the following solutions for the other key variables in terms of the core state variable k_t

(15) $s_t = \left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1-\alpha]Ak_t^{\alpha},$

(16) $x_t = [1+\mu n]\left[\frac{\alpha}{1+n}\right]Ak_t^{\alpha},$

(17) $b_t = \left[[\mu - B + \mu n[1-B]\,][1-\alpha] - [1+\mu n]\alpha\right]\left[\frac{1}{1+n}\right]Ak_t^{\alpha},$

and

(18) $\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i_{t+1} = [1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}.$

Before examining the dynamics of the system implied by these equations, we first find the steady state values for the model's key variables.

1.5 Steady State Analysis

In the Appendix, we show the unique steady state capital value for the model is

(19) $k = \left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}.$

As also shown in the Appendix, the other key steady state values are

(20) $y = A^{\frac{1}{1-\alpha}}\left[\frac{\alpha}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}},$

(21) $w = [1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}},$

(22) $r = n,$

(23) $\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i = 1 + n,$

(24) $s = \left[\frac{\mu - B + \mu n[1-B]}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$,

(25) $x = [1+\mu n]\left[\frac{\alpha A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$,

(26) $b = \left[\mu\left[[1+n[1-B]\,][1-\alpha] - \alpha n\right] - B[1-\alpha] - \alpha\right]\left[\frac{A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$,

(27) $c^y = \mathrm{B}\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$,

and

(28) $c^o = [1-\mathrm{B}][1+\mu n][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

We are interested in understanding how the parameter μ affects the steady state values. From equations (19) - (23), we see μ does not affect the steady state values of k, y, w, r, or i. That is, the extent to which income is earned in young age versus old age does not impact the capital per worker employed in production, the production level, the real wage rate, the capital rental rate, nor the rate of return earned on savings. In the single steady state, the capital rental rate and the interest rate paid on saving are equal to the labor growth rate n.

However, examining the steady state values (24) - (28), we find the parameter μ does affect the demand side of the economy. Differentiating the solution (24), we find $\frac{\partial s}{\partial \mu} = \left[\frac{[1+n[1-B]]}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}} > 0$. Thus, we know the steady state saving level s decreases as μ decreases. That is, as more income is earned in old age, the consumer saves less when young. Examining equation

(25), we similarly see the steady state value of x decreases as the value of μ decreases from 1.

One important question is, "What will allow a bubble to exist in the steady state?" In the Appendix, using equation (26), we show a positive bubble $b > 0$ will exist if and only if $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < \mu \leq 1$. For this condition to hold $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < 1$ must hold. In the Appendix, we show this last condition holds if and only if

(29) $1 - B > \frac{\alpha}{1-\alpha}$.

As long as condition (29) holds, there exists a range of values for μ such that there is a positive bubble. When we differentiate the solution (26), we find $\frac{\partial b}{\partial \mu} = \left[\frac{A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}\left[[1-\alpha] + n\big[[1-B][1-\alpha]-\alpha\big]\right]$ which is positive since we assume $[1-B][1-\alpha]-\alpha > 0$ in condition (29) so bubbles can form. Thus, the steady state bubble also decreases as income is shifted to old age. Because the bubble decreases as μ decreases, we know the largest bubble occurs when $\mu = 1$. Then, as μ decreases to $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$, the bubble decreases to 0. Put differently, we learn that shifting income to old age decreases the steady state bubble, and there will be no bubble if old age income is large enough compared to young age income.

As with the bubble b and the saving level s, the steady state value of x will be the lowest when μ is at its lowest value $\mu = \frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$, and this steady state value for x increases as μ increases until x reaches its maximum when $\mu = 1$. Thus, we learn that shifting income to old age decreases the steady state saving level by both reducing the bubble and the amount of saving flowing into capital.

In the Appendix, we show $c^y = \mathrm{B}\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$ and $c^o = [1-\mathrm{B}][1+\mu n][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$. These are also equal to the Golden Rule steady state values. Interestingly, as the value of μ decreases both c^y and c^o decrease. This indicates that the steady state utility level $U(c^y, c^o) = B\ ln(c^y) + [1-B]ln(c^o) = B\ ln\left(\mathrm{B}\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}\right) + [1-B]ln\left([1-\mathrm{B}][1+\mu n][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}\right)$ is maximized when $\mu = 1$. Thus, if the consumer can choose μ, the consumer should choose $\mu = 1$. That is, the consumer should choose to only work in young age.

1.6 Model Dynamics

The steady state value for the state variable k given in (19) is stable if and only if $0 < \left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t = k} < 1$. In the Appendix, we show $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t = k} = \frac{[n+\delta]\alpha + [1-\delta]}{1+n}$. Thus, the steady state is stable if and only if $0 < \frac{[n+\delta]\alpha + [1-\delta]}{1+n} < 1$, which implies $0 < [\mathrm{n}+\delta]\alpha + [1-\delta] < 1 + \mathrm{n}$, which implies $0 < [\mathrm{n}+\delta]\alpha < \mathrm{n}+\delta$, which implies $0 < \alpha < 1$. Because we assume, $0 < \alpha < 1$, we find that the steady state is stable. Knowing that the steady state is both unique and stable, we know that all variables converge from their initial conditions to their steady state values.

Figure 1.1 presents the equilibrium capital and bubble paths for two equilibrium conditions. In one case, the initial capital stock is below the steady state equilibrium value. In the other case, the initial capital stock is above the steady state equilibrium value. In each case, the capital stock and bubble converge to their steady state equilibrium levels. As shown in the figure, when $\mu = 1$, the highest steady state bubble occurs. The equilibrium paths are shown for two other values of μ, one for the value $\mu = \frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$ and one for $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < \mu < 1$. When μ is at the minimum value $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$ the optimal value for the bubble is zero.

Figure 1.1
Bubble and Capital Levels
(For three different levels for mu)

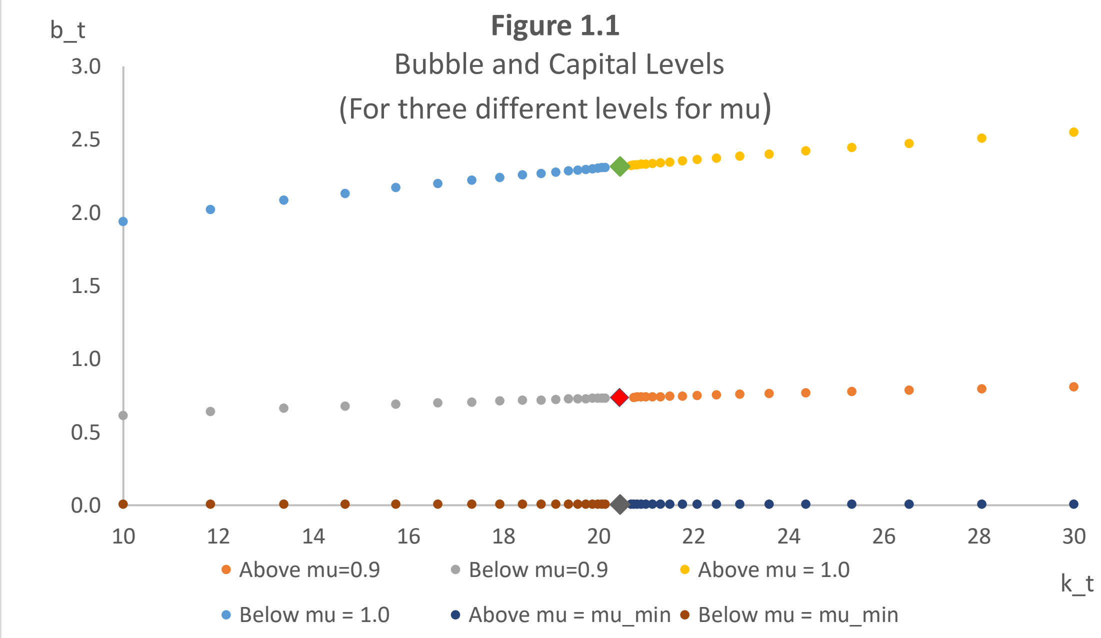


Figure 1.2 presents the total savings level for the generation t consumer, along with the savings placed in the capital backed asset and savings placed in the bubble asset. Separate paths are shown for when capital converges to its equilibrium value from below and from above. When capital converges from below, savings increases, with allocation of savings to the capital asset and bubble asset increasing accordingly. When capital converges from above, savings decreases, with allocation of savings to the capital asset and bubble asset decreasing accordingly.

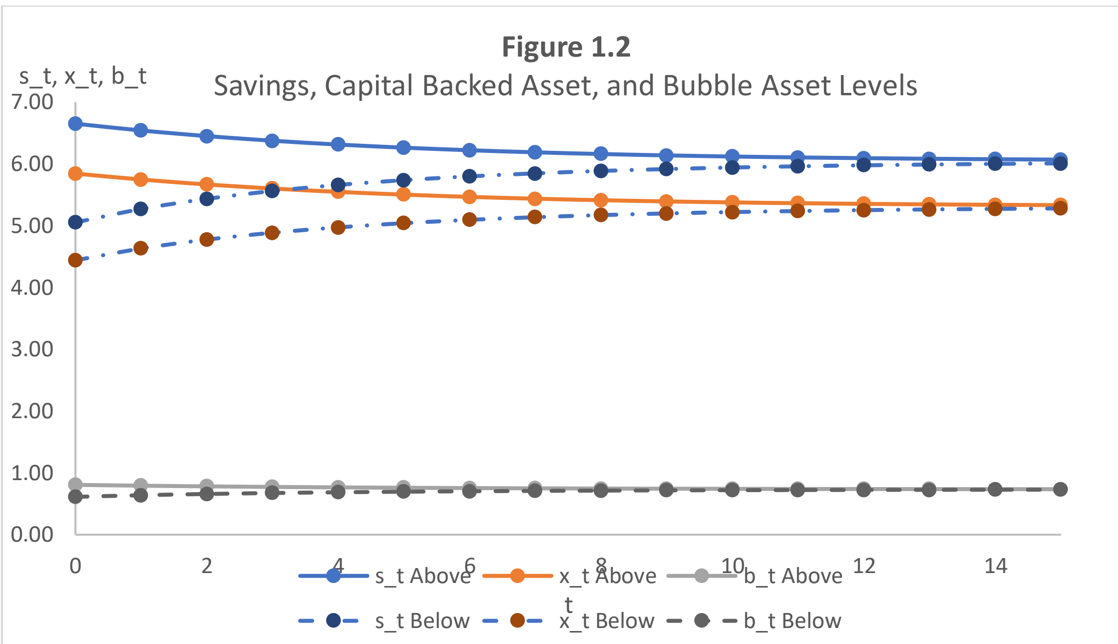
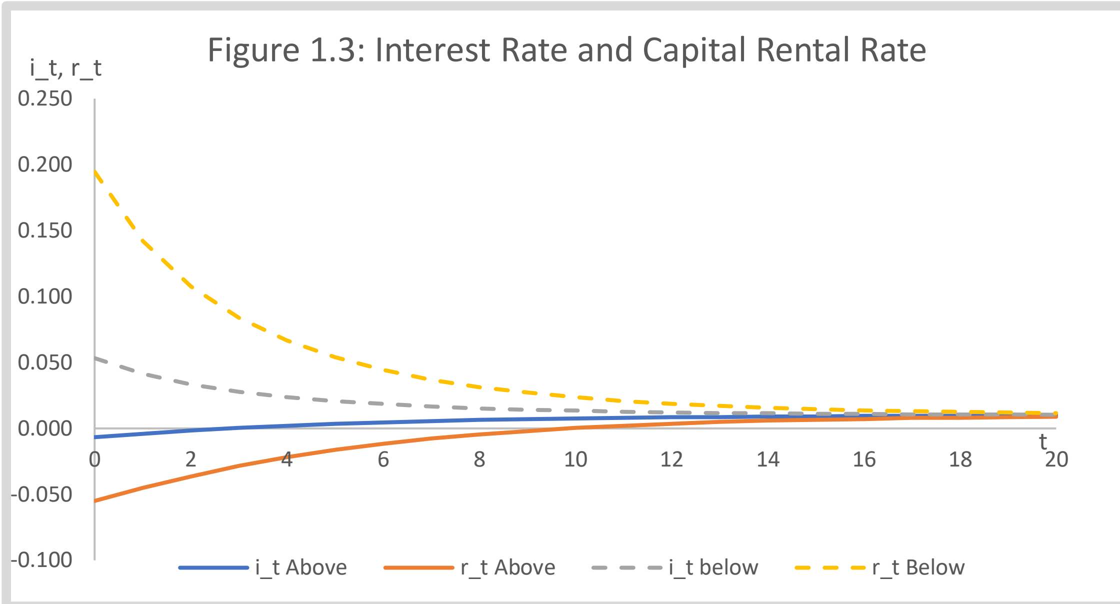


Figure 1.2
Savings, Capital Backed Asset, and Bubble Asset Levels

In the Appendix, we show the proportions of saving $\frac{x_t}{s_t}$ allocated to the capital backed asset and proportion of saving $\frac{b}{s_t}$ allocated to the bubble asset remain constant over time. The proportions are $\frac{x_t}{s_t} = \left[\frac{1+\mu n}{\mu - B + \mu n[1-B]}\right]\left[\frac{\alpha}{1-\alpha}\right]$ and $\frac{b_t}{s_t} = 1 - \frac{1+\mu n}{\mu - B + \mu n[1-B]}\left[\frac{\alpha}{1-\alpha}\right]$. That is, as the economy unfolds and the savings level changes, the percentages of saving allocated to the two assets remain constant. In the Appendix, we find $\frac{\partial}{\partial\mu}\left[\frac{x_t}{s_t}\right] = -\left[\frac{\alpha}{1-\alpha}\right]\left[\frac{1+n}{[\mu - B + \mu n[1-B]]^2}\right] < 0$. That is, we find a decrease in μ increases the percentage of savings allocated to the capital backed asset and decreases the percentage allocated to the bubble asset. In words, as there is a shift in income to old age, the share of saving allocated to the capital backed asset increases, and the share allocated to the bubble decreases. When the parameter μ reaches the minimal level $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$, the allocation to the bubble is zero and all of saving is allocated to the capital backed asset.

Figure 1.3 presents the paths for the interest rate paid on savings and the capital rental rate. Separate paths are shown for when capital converges to its equilibrium value from below and from above. When capital converges from below, the interest rate and capital rental rate each decrease, and the capital rental rate is above the interest rate. When capital converges from above, the interest rate and capital rental rate each increase, and the capital rental rate is below the interest rate. In each case, the rate of population growth n is the attractor. That is, the long term interest rate paid on saving and capital rental rate each approach the rate of population growth, indicating a biological rate of interest.



1.7 Conclusion

The question asked in this paper is, "What happens to the equilibrium path for the OG model with production when the income of a consumer does not all occur in young age?" As our parameter μ decreases from 1, the consumer's income is shifted from young age to old age. What is the impact of this shift?

A first and primary finding is that the path for capital stock k_t does not depend upon the parameter μ, the extent to which income is earned in young age versus old age. This implies the paths for output y_t, real wage w_t, and capital rental rate r_t also do not depend upon the allocation of income, young age versus old age. The path for capital does depend upon the rate of depreciation δ and the population growth rate n. The steady state levels for capital, output, and real wage are higher when the depreciation rate is lower and when the population growth rate is lower.

The paths for saving and its components do depend upon μ. As income is shifted from young age to old (i.e. μ decreases), the steady state savings level decreases, the share of saving allocated to the bubble asset decreases, and the share of saving allocated to the capital backed asset increases. If enough income is earned in old age, then no bubble can arise.

Neither the interest rate nor capital rental rate depend upon μ. They each converge over time to the population growth rate n, indicating the model maintains a biological theory of interest.

We find that the steady state young and old age consumption levels are each increasing in μ, which implies the steady state or Golden Rule utility level is increasing in μ. In our model, the parameter μ is exogenous. However, if it were endogenous, our model indicates consumers should choose to make $\mu = 1$, meaning they should desire to place all labor income in young age. More work is needed to understand why this result holds. It could result from the particular log linear utility function assumed here. It could be because we have restricted our model to parameter values where bubbles can form. It is reasonable that people could adjust their work effort from young age to old age or vise versa. This work provides a bench market for further study of the implications of this decision.

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Mathematical Appendix A

A1. Consumer Problem Derivations:

Deriving the consumer demand functions $\boldsymbol{c_t^y = [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1} + \mu B w_t}$ *and* $\boldsymbol{c_{t+1}^o = [1-\mu][1-B]w_{t+1} + \mu\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t}$, the savings function $\boldsymbol{s_t = [1-B]\mu w_t - [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1}}$, and the gross rate of return condition $\boldsymbol{1+i_t = \frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t}}$.

Substituting conditions (4), (2), and (3) into condition (1), we obtain the young age budget constraint $c_t^y = \mu w_t - v_t\theta_t - p_t m_t$. The consumer's problem is choose the young age consumption level c_t^y, the old age consumption level c_{t+1}^0, the stock demand level θ_t and bubble asset demand level m_t to maximize $U(c_t^y, c_{t+1}^o) = Bln(c_t^y) + [1-B]ln(c_{t+1}^o)$ subject to this constraint and the old age budget constraint (5). The Lagrangian is

$$L = Bln(c_t^y) + [1-B]ln(c_{t+1}^o) + \lambda_1[\mu w_t - v_t\theta_t - p_t m_t - c_t^y]$$
$$+ \lambda_2[[1-\mu]w_{t+1} + p_{t+1}m_t + v_{t+1}\theta_t - c_{t+1}^o]$$

The first order conditions are

$$L_{c_t^y} = \frac{B}{c_t^y} - \lambda_1 = 0$$

$$L_{c_{t+1}^o} = \frac{1-B}{c_{t+1}^o} - \lambda_2 = 0$$

$$L_{\theta_t} = -\lambda_1 v_t + \lambda_2 v_{t+1} = 0$$

$$L_{m_t} = -\lambda_1 p_t + \lambda_2 p_{t+1} = 0$$

$$L_{\lambda_1} = \mu w_t - v_t\theta_t - p_t m_t - c_t^y = 0$$

$$L_{\lambda_2} = [1-\mu]w_{t+1} + p_{t+1}m_t + v_{t+1}\theta_t - c_{t+1}^o = 0.$$

Using $-\lambda_1 v_t + \lambda_2 v_{t+1} = 0$ and $-\lambda_1 p_t + \lambda_2 p_{t+1} = 0$, we find $\frac{\lambda_1}{\lambda_2} = \frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t}$. Defining $1 + i_{t+1}$ as the gross rate of return earned on saving, we find $1 + i_{t+1} = \frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t}$.

Using $\frac{B}{c_t^y} - \lambda_1 = 0$ and $\frac{1-B}{c_{t+1}^o} - \lambda_2 = 0$, we find $\frac{\frac{B}{c_t^y}}{\frac{1-B}{c_{t+1}^o}} = \frac{\lambda_1}{\lambda_2}$, or $\frac{B}{1-B}\frac{c_{t+1}^o}{c_t^y} = \frac{\lambda_1}{\lambda_2}$. Combining this condition with the knowledge that $\frac{\lambda_1}{\lambda_2} = \frac{v_{t+1}}{v_t}$, we find $\frac{B}{1-B}\frac{c_{t+1}^o}{c_t^y} = \frac{v_{t+1}}{v_t}$, or $c_{t+1}^o = \frac{v_{t+1}}{v_t}\frac{1-B}{B}c_t^y$. Starting with the old age budget constraint (5) and using conditions (2) and (3), we obtain

$c_{t+1}^o = [1-\mu]w_{t+1} + \frac{p_{t+1}}{p_t}b_t + \frac{v_{t+1}}{v_t}x_t$. Using the result, $\frac{p_{t+1}}{p_t} = \frac{v_{t+1}}{v_t}$, we find $c_{t+1}^o = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}[b_t + x_t]$, which using (4) implies $c_{t+1}^o = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}s_t$. Using (1), we then find $c_{t+1}^o = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}\left[\mu w_t - c_t^y\right]$. Combining our two conditions for c_{t+1}^o, we find $\frac{v_{t+1}}{v_t}\frac{1-B}{B}c_t^y = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}\left[\mu w_t - c_t^y\right]$, which implies $\frac{v_{t+1}}{v_t}\left[\frac{1-B}{B}c_t^y + c_t^y\right] = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}\mu w_t$, which implies $\frac{v_{t+1}}{v_t}\left[\frac{1}{B}\right]c_t^y = [1-\mu]w_{t+1} + \frac{v_{t+1}}{v_t}\mu w_t$, which implies $c_t^y = [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1} + \mu B w_t$. Using this solution for c_t^y, we find $c_{t+1}^o = \frac{v_{t+1}}{v_t}\frac{1-B}{B}c_t^y = \frac{v_{t+1}}{v_t}\frac{1-B}{B}\left[[1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1} + \mu B w_t\right]$, or

$c_{t+1}^{o} = [1-\mu][1-B]w_{t+1} + \mu\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t$. Using the solution for c_t^y and budget constraint (1), we find $[1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1} + \mu B w_t + s_t = \mu w_t$, or $s_t = [1-B]\mu w_t - [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1}$.

A2. Finding the minimum value of μ

Prove that $\mathbf{s_t > 0}$ implies $\boldsymbol{\mu} > \frac{\mathbf{Bw_{t+1}}}{\left[\frac{\mathbf{v_{t+1}}}{\mathbf{v_t}}\right][\mathbf{1-B}]\boldsymbol{w_t}+\mathbf{Bw_{t+1}}}$

From using the condition (15), we have $s_t = [1-B]\mu w_t - [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1}$, which implies $s_t = \mu w_t - B\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}}w_{t+1}\right]$. Setting $s_t > 0$, we have $\mu w_t - B\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}}w_{t+1}\right] > 0$. Multiplying and rearranging, we have $\mu w_t[1-B] - \frac{B-B\mu}{\frac{v_{t+1}}{v_t}}w_{t+1} > 0$, which implies $\mu w_t - B\left[\mu w_t + \frac{[1-\mu]}{\frac{v_{t+1}}{v_t}}w_{t+1}\right] > 0$, which implies $\mu w_t - B\mu w_t - \frac{B-B\mu}{\frac{v_{t+1}}{v_t}}w_{t+1} > 0$, which implies $\mu w_t[1-B] - \frac{B-B\mu}{\frac{v_{t+1}}{v_t}}w_{t+1} > 0$, which implies $\mu w_t[1-B]\frac{v_{t+1}}{v_t} - [B-B\mu]w_{t+1} > 0$, which implies $\mu w_t[1-B]\frac{v_{t+1}}{v_t} + B\mu w_{t+1} - Bw_{t+1} > 0$, which implies $\mu\left[w_t[1-B]\frac{v_{t+1}}{v_t} + Bw_{t+1}\right] > Bw_{t+1}$, which implies $\mu > \frac{Bw_{t+1}}{\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t + Bw_{t+1}}$.

A3. Finding the general equilibrium of k_{t+1}

Proof that in general equilibrium $\boldsymbol{k_{t+1}} = \left[\frac{\alpha A}{1+n}\right]\boldsymbol{k_t^{\alpha}} + \left[\frac{1-\delta}{1+n}\right]\boldsymbol{k_t}$:

Multiplying the stock market clearing condition (12) by the price v_t, we obtain $v_t\theta_{t-1} = [1+n]v_t\theta_t$. From condition (5), we know $c_t^o = [1-\mu]w_t + p_t m_{t-1} + v_t\theta_{t-1}$, which implies $v_t\theta_{t-1} = c_t^o - [1-\mu]w_t - p_t m_{t-1}$. Substituting this result into our previous condition, we obtain $[1+n]v_t\theta_t = c_t^o - [1-\mu]w_t - p_t m_{t-1}$. Using (2) to eliminate x_t from the saving condition (4), we find $v_t\theta_t = s_t - b_t$. Using this result, our previous condition becomes $[1+n][s_t - b_t] = c_t^o - [1-\mu]w_t - p_t m_{t-1}$. We can rewrite this equation as $[1+n][s_t - b_t] = c_t^o - [1-\mu]w_t - \frac{p_t}{p_{t-1}}p_{t-1}m_{t-1}$, which using (3) we can rewrite as $[1+n][s_t - b_t] = c_t^o - [1-\mu]w_t - \frac{p_t}{p_{t-1}}b_{t-1}$, or $[1+n]s_t = c_t^o - [1-\mu]w_t + [1+n]b_t - \frac{p_t}{p_{t-1}}b_{t-1}$.

We now show this latter condition reduces to $[1+n]s_t = c_t^o - [1-\mu]w_t$ because $[1+n]b_t - \frac{p_t}{p_{t-1}}b_{t-1} = 0$. Starting with the bubble asset clearing condition (13), we have $m_{t-1} = [1+n]m_t$. Multiplying by p_t, we obtain $p_t m_{t-1} = [1+n]p_t m_t$, which we can rewrite as $\frac{p_t}{p_{t-1}}p_{t-1}m_{t-1} = [1+n]p_t m_t$. Using (3), we then obtain the desired result $\frac{p_t}{p_{t-1}}b_{t-1} = [1+n]b_t$.

Knowing $[1+n]s_t = c_t^o - [1-\mu]w_t$, we use condition (1) to obtain $[1+n]\left[\mu w_t - c_t^y\right] = c_t^o - [1-\mu]w_t$, which we can rewrite as $\mu w_t + [1-\mu]\frac{w_t}{1+n} = c_t^y + \frac{c_t^o}{1+n}$. Multiplying by $\frac{1+n}{1+\mu n}$, we obtain $\left[\frac{1+n}{1+\mu n}\right]\left[\mu w_t + [1-\mu]\frac{w_t}{1+n}\right] = \left[\frac{1+n}{1+\mu n}\right]\left[c_t^y + \frac{c_t^o}{1+n}\right]$. Adding $[1+n]k_{t+1} - [1-\delta]k_t - y_t$, we obtain $\left[\frac{1+n}{1+\mu n}\right]\left[\mu w_t + [1-\mu]\frac{w_t}{1+n}\right] + [1+n]k_{t+1} - [1-\delta]k_t - y_t = \left[\frac{1+n}{1+\mu n}\right]\left[c_t^y + \frac{c_t^o}{1+n}\right] + [1+n]k_{t+1} - [1-\delta]k_t - y_t$. The left side of this last equation is the excess demand for output, so when we impose the product market clearing condition (11) we obtain $\left[\frac{1+n}{1+\mu n}\right]\left[\mu w_t + [1-\mu]\frac{w_t}{1+n}\right] + [1+n]k_{t+1} - [1-\delta]k_t - y_t = 0$, which can be rewritten $y_t = \left[\frac{1+n}{1+\mu n}\right]\left[w_t\left[\frac{1+\mu n}{1+n}\right]\right] + [1+n]k_{t+1} - [1-\delta]k_t$, which implies $y_t = w_t + [1+n]k_{t+1} - [1-\delta]k_t$. Together, conditions (5), (8), and (9) imply $w_t = y_t - [r_t+\delta]k_t$. Using this to replace w_t in the previous condition, we obtain $y_t = y_t - [r_t+\delta]k_t + [1+n]k_{t+1} - [1-\delta]k_t$, which implies $k_{t+1} = \frac{[1+r_t]}{[1+n]}k_t$. Using condition (8), we obtain $k_{t+1} = \frac{[1-\delta + \alpha A k_t^{\alpha-1}]}{[1+n]}k_t$, or $k_{t+1} = \left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k_t$.

A4. Deriving the equilibrium values for key parameters

Deriving the equilibrium values *for* $\boldsymbol{s_t = \left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1-\alpha]A}$, $\boldsymbol{x_t = [1+\mu n]\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha}}$, $\boldsymbol{\frac{v_{t+1}}{v_t} = [1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}}$, $\boldsymbol{b_t = [[\mu - B + \mu n[1-B]\,][1-\alpha] - [1+\mu n]\alpha]\left[\frac{1}{1+n}\right]Ak_t^{\alpha}}$, $\boldsymbol{\frac{v_{t+1}}{v_t} = [1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}}$**:**

From using the condition (15), we have $s_t = [1-B]\mu w_t - [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}w_{t+1}$. Using (9), we obtain $s_t = [1-B]\mu[1-\alpha]Ak_t^{\alpha} - [1-\mu]\frac{B}{\frac{v_{t+1}}{v_t}}[1-\alpha]Ak_{t+1}^{\alpha}$. To find the value of $\frac{v_{t+1}}{v_t}$, we update condition (12) one period to obtain $\theta_t = [1+n]\theta_{t+1}$. Multiplying by v_t, we obtain $v_t\theta_t = [1+n]\frac{v_t}{v_{t+1}}v_{t+1}\theta_{t+1}$. Using condition (2), we have $x_t = [1+n]\frac{v_t}{v_{t+1}}x_{t+1}$. Rearranging, we have $\frac{v_{t+1}}{v_t} = [1+n]\frac{x_{t+1}}{x_t}$. Applying condition (15), we have $\frac{v_{t+1}}{v_t} = [1+n]\frac{[1+\mu n]\left[\frac{\alpha A}{1+n}\right]k_{t+1}^{\alpha}}{[1+\mu n]\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha}}$, which becomes $\frac{v_{t+1}}{v_t} = [1+n]\left[\frac{k_{t+1}}{k_t}\right]^{\alpha}$. Applying condition (14), $\frac{v_{t+1}}{v_t} = [1+n]\left[\frac{\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k_t}{k_t}\right]^{\alpha}$, which becomes $\frac{v_{t+1}}{v_t} = [1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}$.

Using the solution for $\frac{v_{t+1}}{v_t}$, we have $s_t = [1-B]\mu[1-\alpha]Ak_t^{\alpha} - [1-\mu]\frac{B}{[1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1}+\left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}}[1-\alpha]Ak_{t+1}^{\alpha}$. Using condition (14), we have $s_t = [1-B]\mu[1-\alpha]Ak_t^{\alpha} - [1-\mu]\frac{B}{[1+n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha-1}+\left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}}[1-\alpha]A\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k_t\right]^{\alpha}$.

Simplifying, we obtain $s_t = [1-B]\mu[1-\alpha]Ak_t^{\alpha} - [1-\mu]\frac{B}{[1+n]}[1-\alpha]Ak_t^{\alpha}$, which implies $s_t = [1-B]\mu[1-\alpha]Ak_t^{\alpha} - [1-\mu]\frac{B}{[1+n]}[1-\alpha]Ak_t^{\alpha}$. Using a common denominator, we have $\left[\frac{[1-B]\mu[1+n]-[1-\mu]B}{[1+n]}\right][1-\alpha]Ak_t^{\alpha}$, which implies $s_t = \left[\frac{[1-B]\mu + [1-B]\mu n - [1-\mu]B}{[1+n]}\right][1-\alpha]Ak_t^{\alpha}$. Simplifying, we obtain $s_t = \left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1-\alpha]Ak_t^{\alpha}$.

From condition (10) we have $x_t = [1+\mu n]k_{t+1} - \frac{[1-\delta][1+\mu n]}{[1+n]}k_t$. Using condition (14), we then find $x_t = [1+\mu n]\left[\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k_t\right] - \frac{[1-\delta][1+\mu n]}{[1+n]}k_t$, which implies $x_t = [1+\mu n]\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + [1+\mu n]\left[\frac{1-\delta}{1+n}\right]k_t - \frac{[1-\delta][1+\mu n]}{[1+n]}k_t$, or $x_t = [1+\mu n]\left[\frac{\alpha A}{1+n}\right]k_t^{\alpha}$.

From condition (4), we rearrange and obtain $b_t = s_t - x_t$. Using the results of s_t and x_t from previous steps, we obtain $b_t = \left[[\mu - B + \mu n[1-B]\,][1-\alpha] - [1+\mu n]\alpha\right]\left[\frac{1}{1+n}\right]Ak_t^{\alpha}$.

A5. Finding the Steady State Values

Proofs that the Steady State Values for the model are $\boldsymbol{k = \left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}}$***,***

$\boldsymbol{y = A^{\frac{1}{1-\alpha}}\left[\frac{\alpha}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$, $\boldsymbol{s = \left[\frac{\mu[1+n[1-B]]-B}{[1+n]}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$,

$\boldsymbol{x = [1+\mu n]\left[\frac{\alpha A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$, $\boldsymbol{b = \left[\mu\left[[1-\alpha] + n[1-B][1-\alpha] - \alpha n\right] - B[1-\alpha] - \alpha\right]\left[\frac{A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$, $\boldsymbol{\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i_{t+1} = 1+n}$, $\boldsymbol{w = [1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$,

$\boldsymbol{r = n}$, $\boldsymbol{c^y = \mathrm{B}\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$, **and** $\boldsymbol{c^o = [1+\mu n][1-\mathrm{B}][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}}$

Starting with condition (14), we have $k_{t+1} = \left[\frac{\alpha A}{1+n}\right]k_t^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k_t$. In a steady state, $k_{t+1} = k_t = k$, which implies $k = \left[\frac{\alpha A}{1+n}\right]k^{\alpha} + \left[\frac{1-\delta}{1+n}\right]k$. We see there is a trivial steady state where $k = 0$. To find the non-trivial steady state, we divide by $k \neq 0$ and obtain $1 = \left[\frac{\alpha A}{1+n}\right]k^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]$. Solving and rearranging, we find the steady state capital stock level $k = \left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}$.

Using condition (7) and imposing stationarity, we obtain $y = Ak^{\alpha}$. Using the solution for k, we arrive at $y = A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which implies $y = A^{\frac{1}{1-\alpha}}\left[\frac{\alpha}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

Using condition (15) and imposing stationarity, we obtain, $s = \left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1 - \alpha]Ak^{\alpha}$. Replacing k with the previous result, we have $s = \left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1 - \alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which implies

$s = \left[\frac{\mu[1+n[1-B]]-B}{[1+n]}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

Imposing stationarity and the value of the steady state capital stock level on condition (16), we obtain $x = [1 + \mu n]\left[\frac{\alpha A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

Using the condition (17) and imposing stationarity, we obtain $b = \left[[\mu - B + \mu n[1-B]\,][1-\alpha] - [1+\mu n]\alpha\right]\left[\frac{A}{1+n}\right]k^{\alpha}$. Using the steady state capital stock level to eliminate k, we obtain $b = \left[[\mu - B + \mu n[1-B]\,][1-\alpha] - [1 + \mu n]\alpha\right]\left[\frac{A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which implies $b = \left[\mu\left[\left[[1+n[1-B]]\right][1-\alpha] - \alpha n\right] - B[1-\alpha] - \alpha\right]\left[\frac{A}{1+n}\right]\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

Imposing stationarity and using the steady state capital stock level in condition (18), we obtain $\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i_{t+1} = [1+n]\left[\left[\frac{\alpha A}{1+n}\right]\left[\left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}\right]^{\alpha-1} + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}$.

Rearranging and simplifying, we find $\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i_{t+1} = [1+n]\left[\left[\frac{n+\delta}{1+n}\right] + \left[\frac{1-\delta}{1+n}\right]\right]^{\alpha}$, which implies $\frac{v_{t+1}}{v_t} = \frac{p_{t+1}}{p_t} = 1 + i_{t+1} = 1 + n$.

By imposing stationarity on condition (9), we arrive at $w = [1-\alpha]Ak^{\alpha}$. Applying the steady state capital stock level, we obtain $w = [1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

Using condition (8) and imposing stationary, we obtain $r = \alpha A k^{\alpha-1} - \delta$. Plugging in the value of the steady state capital stock level and re-arranging, we have $r = \alpha A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha-1}{1-\alpha}} - \delta$, which implies $r = n$.

By solving the consumer problem above, we found that the young age consumption level is $\mathrm{c}_{\mathrm{t}}^{\mathrm{y}} = \mathrm{B}\left[\mu \mathrm{w}_{\mathrm{t}} + \frac{[1-\mu]}{\frac{\mathrm{v}_{\mathrm{t}+1}}{\mathrm{v}_{\mathrm{t}}}}\mathrm{w}_{\mathrm{t}+1}\right]$. When we impose stationarity, we obtain $c^{y} = \mathrm{Bw}\left[\mu + \frac{[1-\mu]}{\frac{\mathrm{v}_{\mathrm{t}+1}}{\mathrm{v}_{\mathrm{t}}}}\right]$. Plugging in the steady state values of w and $\frac{\mathrm{v}_{\mathrm{t}+1}}{\mathrm{v}_{\mathrm{t}}}$, we have $c^{y} = \mathrm{B}\left[\mu + \frac{[1-\mu]}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which implies $c^{y} = \mathrm{B}\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$. From the optimization problem for the consumer, we find the optimal old age consumption level is $c_{t+1}^{o} = [1-\mu][1-B]w_{t+1} + \mu\left[\frac{v_{t+1}}{v_t}\right][1-B]w_t$. Imposing the stationarity, we obtain $c^{o} = [1-\mu][1-B]w + \mu\left[\frac{v_{t+1}}{v_t}\right][1-B]w$, i which implies $c^{o} = \left[[1-\mu] + \mu\left[\frac{v_{t+1}}{v_t}\right]\right][1-B]w$. Using the steady state values of w and $\frac{\mathrm{v}_{\mathrm{t}+1}}{\mathrm{v}_{\mathrm{t}}}$, we obtain $c^{o} = \big[[1-\mu] + \mu[1+n]\big][1-B][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which reduces to

$$c^{o} = [1+\mu n][1-B][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}.$$

A6. Proof that $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=k} = \frac{[n+\delta]\alpha+[1-\delta]}{1+n}$:

From condition (14), we take the derivative of k_{t+1} with respect to k_t, resulting with $\frac{\partial k_{t+1}}{\partial k_t} = \left[\frac{\alpha A}{1+n}\right]\alpha k_t^{\alpha-1} + \frac{1-\delta}{1+n}$. Setting the value of k_t equal to the steady state value (19), we have $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=k} = \left[\frac{\alpha A}{1+n}\right]\alpha\left[\left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}\right]^{\alpha-1} + \frac{1-\delta}{1+n}$, which implies $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=k} = \left[\frac{\alpha A}{1+n}\right]\alpha\left[\frac{n+\delta}{\alpha A}\right] + \frac{1-\delta}{1+n}$. Rearranging, we arrive at $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=k} = \left[\frac{n+\delta}{1+n}\right]\alpha + \frac{[1-\delta]}{1+n}$, which implies $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=\bar{k}} = \frac{[n+\delta]\alpha+[1-\delta]}{1+n}$, which implies $\left.\frac{\partial k_{t+1}}{\partial k_t}\right|_{k_t=\bar{k}} = \frac{[n+\delta]\alpha+[1-\delta]}{1+n}$.

A7. Proof that $b > 0$ if and only if $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < \mu \leq 1$:

From the steady state solution (26), $b > 0$ implies

$\mu\left[\left[[1+n[1-B]]\right][1-\alpha] - \alpha n\right] - B[1-\alpha] - \alpha > 0$, which implies $\mu\left[\left[[1+n[1-B]]\right][1-\alpha] - \alpha n\right] > B[1-\alpha] + \alpha$, which implies $\mu > \frac{B[1-\alpha]+\alpha}{\left[[1+n[1-B]]\right][1-\alpha]-\alpha n}$, which implies $\mu > \frac{B[1-\alpha]+\alpha}{[1-\alpha]+n[1-B][1-\alpha]-\alpha n}$, which implies $\mu > \frac{B[1-\alpha]+\alpha}{[1-\alpha]+n[1-\alpha]-nB[1-\alpha]-n\alpha}$, which implies $\mu > \frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]}$.. Since $\mu \leq 1$ must also hold because it is not possible to work more than 100 percent of time in young age, we find $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < \mu \leq 1$.

A8. Proof that $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < 1$ implies $1-B > \frac{\alpha}{1-\alpha}$:

The condition $\frac{B[1-\alpha]+\alpha}{[1+n][1-\alpha]-n[B[1-\alpha]+\alpha]} < 1$ implies $[1+n][1-\alpha] - n[B[1-\alpha]+\alpha] > B[1-\alpha]+\alpha$, which implies $[1+n][1-\alpha] > [1+n][B[1-\alpha]+\alpha]$, which implies $1-\alpha > B[1-\alpha]+\alpha$, which implies $[1-B][1-\alpha] > \alpha$, which implies $1-B > \frac{\alpha}{1-\alpha}$.

***A9. Derivation of Golden Rule Values*:**

The Golden Rule allocation is the steady state that maximizes the utility of the representative consumer.

The Golden Rule allocation must satisfy the product market clearing condition (11), $y_t = \left[\frac{1+n}{1+\mu n}\right]\left[c_t^y + \left[\frac{1}{1+n}\right] c_t^o\right] + [1+n]k_{t+1} - [1-\delta]k_t$. Imposing the steady state condition, we obtain $y = \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right] c^o\right] + [1+n]k - [1-\delta]k$. Using condition (7), we obtain $Ak^\alpha = \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right] c^o\right] + [n+\delta]k$. This is the consumer's consumption possibilities constraint.

The Golden Rule is obtained when the representative consumer maximizes the utility given the consumption possibilities constraint. In the steady state, the representative consumer's utility function $U\left(c_t^y, c_{t+1}^o\right) = Bln\left(c_t^y\right) + [1-B]ln(c_{t+1}^o)$ becomes $U(c^y, c^o) = Bln(c^y) + [1-B]ln(c^o)$.

Using the Lagrangian approach, we have: $L = Bln(c^y) + [1-B]ln(c^o) + \lambda\left[Ak^\alpha - \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right] c^o\right] - [n+\delta]k\right]$. This yields the first order conditions,

$L_{c^y} = \frac{B}{c^y} - \left[\frac{1+n}{1+\mu n}\right]\lambda = 0$, $L_{c^o} = \frac{1-B}{c^o} - \lambda\frac{1}{1+\mu n} = 0$, $L_k = \alpha A k^{\alpha-1} - [n+\delta] = 0$, and $L_\lambda = Ak^\alpha - \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right]\ c^o\right] - [n+\delta]k = 0$.

The condition $\alpha Ak^{\alpha-1} - [n+\delta] = 0$ implies $\alpha Ak^{\alpha-1} = n+\delta$ which implies $k^{\alpha-1} = \frac{n+\delta}{\alpha A}$ which implies $k = \left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}$. This is the Golden Rule level for k.

To find the Golden Rule consumption levels, we use $L_{c^y} = \frac{B}{c^y} - \left[\frac{1+n}{1+\mu n}\right]\lambda = 0$ to obtain $\frac{B}{c^y} = \left[\frac{1+n}{1+\mu n}\right]\lambda$, and we use $L_{c^o} = \frac{1-B}{c^o} - \lambda\frac{1}{1+\mu n} = 0$ to obtain $\frac{1-B}{c^o} = \lambda\frac{1}{1+\mu n}$.

Therefore $\frac{\frac{B}{c^y}}{\frac{1-B}{c^o}} = \frac{\left[\frac{1+n}{1+\mu n}\right]\lambda}{\lambda\frac{1}{1+\mu n}}$, which implies $\frac{Bc^o}{[1-B]c^y} = \frac{[[1+n]\lambda[1+\mu n]]}{[1+\mu n]\lambda}$, which implies $\frac{Bc^o}{[1-B]c^y} = 1+n$, which implies $c^o = \frac{[1+n][1-B]}{B}c^y$. Next, $L_\lambda = Ak^\alpha - \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right]\ c^o\right] - [n+\delta]k = 0$ implies $Ak^\alpha = \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right]\ c^o\right] + [n+\delta]k$. Using our relationship $c^o = \frac{[1+n][1-B]}{B}c^y$, we can then obtain $Ak^\alpha = \left[\frac{1+n}{1+\mu n}\right]\left[c^y + \left[\frac{1}{1+n}\right]\frac{[1+n][1-B]}{B}c^y\right] + [n+\delta]k$, which implies $Ak^\alpha = \left[\frac{1+n}{1+\mu n}\right]c^y\left[1 + \frac{[1-B]}{B}\right] + [n+\delta]k$, which implies $Ak^\alpha - [n+\delta]k = \left[\frac{1+n}{1+\mu n}\right]c^y\left[\frac{1}{B}\right]$, which implies $c^y = B\left[\frac{1+\mu n}{1+n}\right][Ak^\alpha - [n+\delta]k]$. Using the condition $L_k = \alpha Ak^{\alpha-1} - [n+\delta] = 0$, we obtain $c^y = B\left[\frac{1+\mu n}{1+n}\right][Ak^\alpha - \alpha Ak^{\alpha-1}k]$, which implies $c^y = B\left[\frac{1+\mu n}{1+n}\right][Ak^\alpha - \alpha Ak^\alpha]$, which implies $c^y = B\left[\frac{1+\mu n}{1+n}\right]Ak^\alpha[1-\alpha]$. Using the solution $k = \left[\frac{\alpha A}{n+\delta}\right]^{\frac{1}{1-\alpha}}$, we finally obtain $c^y = B\left[\frac{1+\mu n}{1+n}\right][1-\alpha]A\left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$. Next, using our condition above $c^o = \frac{[1+n][1-B]}{B} c^y$, we find $c^o = \frac{[1+n][1-B]}{B} B \left[\frac{1+\mu n}{1+n}\right] [1 - \alpha] A \left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$, which implies $c^o = [1+\mu n][1-B][1-\alpha] A \left[\frac{\alpha A}{n+\delta}\right]^{\frac{\alpha}{1-\alpha}}$.

A10. Proof that $\frac{x_t}{s_t} = \left[\frac{1+\mu n}{\mu - B + \mu n[1-B]}\right]\left[\frac{\alpha}{1-\alpha}\right]$ and $\frac{b_t}{s_t} = 1 - \frac{1+\mu n}{\mu - B + \mu n[1-B]}\left[\frac{\alpha}{1-\alpha}\right]$:

Using the solutions (15) and (16), we obtain $\frac{x_t}{s_t} = \frac{[1+\mu n]\left[\frac{\alpha}{1+n}\right] A k_t^{\alpha}}{\left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1-\alpha] A k_t^{\alpha}}$, which becomes $\frac{x_t}{s_t} = \frac{[1+\mu n][\alpha]}{[\mu - B + \mu n[1-B]][1-\alpha]}$, which becomes $\frac{x_t}{s_t} = \left[\frac{1+\mu n}{\mu - B + \mu n[1-B]}\right]\left[\frac{\alpha}{1-\alpha}\right]$.

Using the solutions (15) and (16), we obtain $\frac{b_t}{s_t} = \frac{[[\mu - B + \mu n[1-B]][1-\alpha] - [1+\mu n]\alpha]\left[\frac{1}{1+n}\right] A k_t^{\alpha}}{\left[\frac{\mu - B + \mu n[1-B]}{[1+n]}\right][1-\alpha] A k_t^{\alpha}}$, which becomes $\frac{b_t}{s_t} = \frac{[\mu - B + \mu n[1-B]][1-\alpha] - [1+\mu n]\alpha}{[\mu - B + \mu n[1-B]][1-\alpha]}$, which becomes $\frac{b_t}{s_t} = 1 - \frac{1+\mu n}{\mu - B + \mu n[1-B]}\left[\frac{\alpha}{1-\alpha}\right]$.

A11. Proof that $\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = -\left[\frac{\alpha}{1-\alpha}\right]\left[\frac{1+n}{[\mu - B + \mu n[1-B]]^2}\right] < 0$:

Using our result $\frac{x_t}{s_t} = \left[\frac{1+\mu n}{\mu - B + \mu n[1-B]}\right]\left[\frac{\alpha}{1-\alpha}\right]$, we find $\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = \frac{\partial}{\partial \mu}\left[\frac{[1+\mu n]}{\mu - B + \mu n[1-B]}\right]\left[\frac{\alpha}{1-\alpha}\right]$, which implies $\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = \frac{\partial}{\partial \mu}[1+\mu n][\mu - B + \mu n[1-B]]^{-1}\left[\frac{\alpha}{1-\alpha}\right]$, which implies $\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = n[\mu - B + \mu n[1-B]]^{-1}\left[\frac{\alpha}{1-\alpha}\right] - [1+\mu n][\mu - B + \mu n[1-B]]^{-2}[1 + n[1-B]]\left[\frac{\alpha}{1-\alpha}\right]$, which implies $\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = \frac{n\left[\frac{\alpha}{1-\alpha}\right][\mu - B + \mu n[1-B]]}{[\mu - B + \mu n[1-B]]^2} - \frac{[1+\mu n][1+n[1-B]]\left[\frac{\alpha}{1-\alpha}\right]}{[\mu - B + \mu n[1-B]]^2}$, which implies

$\frac{\partial}{\partial \mu}\left[\frac{x_t}{s_t}\right] = \left[\frac{\alpha}{1-\alpha}\right]\left[\frac{[n\mu - n B + n\mu n[1-B]] - [1+\mu n] - [1+\mu n]n[1-B]}{[\mu - B + \mu n[1-B]]^2}\right]$, which implies

$$\frac{\partial}{\partial\mu}\left[\frac{x_t}{s_t}\right] = \left[\frac{\alpha}{1-\alpha}\right]\left[\frac{n\mu - n\,B + n\mu n - n\mu nB - 1 - \mu n - n[1+\mu n] + n[1+\mu n]B}{\left[\mu - B + \mu n[1-B]\right]^2}\right]$$, which implies

$$\frac{\partial}{\partial\mu}\left[\frac{x_t}{s_t}\right] = \left[\frac{\alpha}{1-\alpha}\right]\left[\frac{-n\,B + n\mu n - n\mu nB - 1 - n - n\mu n + nB + n\mu nB}{\left[\mu - B + \mu n[1-B]\right]^2}\right]$$, which implies

$$\frac{\partial}{\partial\mu}\left[\frac{x_t}{s_t}\right] = \left[\frac{\alpha}{1-\alpha}\right]\left[\frac{-1-n}{\left[\mu - B + \mu n[1-B]\right]^2}\right]$$, which implies

$$\frac{\partial}{\partial\mu}\left[\frac{x_t}{s_t}\right] = -\left[\frac{\alpha}{1-\alpha}\right]\left[\frac{1+n}{\left[\mu - B + \mu n[1-B]\right]^2}\right] < 0$$

Chapter 2

Do Foreign Remittances Help Reduce Household Poverty? Evidences from Vietnam

2.1 Abstract

Over the last few decades, there has been an increase in international remittances worldwide. This paper investigates the relationship between international remittances and poverty in Vietnamese households. Utilizing the Vietnamese Households Living Standard Surveys from 2004 to 2016, our probit models indicate that international remittances reduce the likelihood of a household being in poverty by 11 to 14 percentage points. Furthermore, using instrumental variables, a bivariate analysis estimates confirm that the impact on poverty reduction is more pronounced for remittances originating from oversea compared to domestic remittances. This finding holds significant implications for policymakers, providing insights into the effective use of remittances and foreign labor migration as strategies to alleviate poverty in Vietnam.

2.2 Introduction

On a global scale, the period from 2000 to 2016 witnessed a substantial surge in migration, the United Nations (2016) estimated a 41 percent increase, resulting in approximately 244 million people residing outside their country of birth. Migration carries inherent advantages. Beyond serving as a vital source of labor, migrants often acquire new skills, expand their knowledge base, and realize an augmented income. A notable portion of this enhanced income is allocated to cover living expenses, some are saved, while as much as 73 percent is directed back home in the form of remittances (Amuedo-Dorantes, 2006).

Remittances serve a multitude of purposes, from reflecting diverse expressions of care and love to altruism. Most migrants send money back to their families back home to fulfill essential needs, encompassing necessities such as food, housing, and recurring living costs. In some developing countries, remittances stand out as a primary source of income for households receiving them. Another significant purpose is investment, extending to both physical and intellectual assets. For instance, remittances may be directed towards housing market investments or funding educational courses for family members. As per Amuedo-Dorantes (2006), households receiving remittances demonstrate a higher likelihood of maintaining academic focus. One additional important reason for remittance is to serve as a type of insurance. When migrants face financial difficulties, they can send money back home to support their families. This creates a reciprocal arrangement where family members reciprocate by helping the migrant in times of need.

In contrast, a notable disadvantage of households receiving remittances is the potential reduction of motivation to increase income by learning new skills, finding new jobs, or developing a business. Rather than serving as an incentive for entrepreneurial endeavors, remittances can act as a line of credit, easing capital constraints and potentially diminishing the drive among family members to explore new economic opportunities.

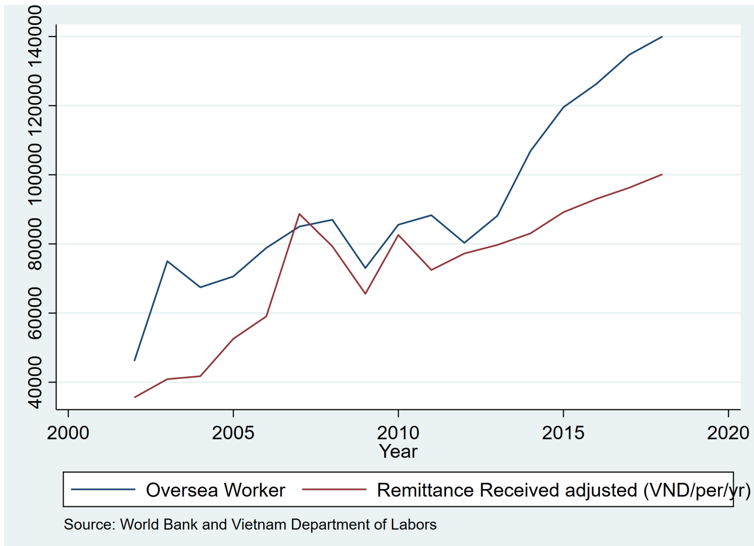
Amuedo-Dorantes (2006) examines households in Latin America and suggests that those receiving remittances are less likely to become business owners. When remittances cover basic needs, shelter, and recurring bills, there may be less impetus to engage in entrepreneurial activities and seek avenues for income enhancement.

In the last 20 years, Vietnam has undergone significant growth in both internal and foreign labor migration. By analyzing the 1999 Population and Housing Census, (Dang et al., 2003) proposes that approximately 6.5 percent of the Vietnamese population relocated from rural to urban areas between 1994 and 1999. This migration trend has been particularly noticeable among young adults moving from rural regions to larger cities for higher education purposes, or to find new economic opportunities that provide higher income. In addition, since its legalization in 1999, highly skilled Vietnamese workers have explored opportunities in other countries. In the last decades, the trend has experienced substantial growth.

Figure 2.1 illustrates the trends in remittances (denoted in Vietnamese Dong) and overseas employment from 2002 to 2018. During this period, overseas employment increased tremendously. In 2004, according to the Ministry of Labor, Invalids and Social Affairs, there were 67447 Vietnamese workers in other countries. By 2018, the number increased to over 140,000 workers. Simultaneously, the amount of remittances witnessed a 5 times increase, from just about 2.31 billion USD in 2004 to over 10 billion USD in 2018, securing its position in the top ten countries with the highest remittance receipts.

Although previous work in literature has been investigating the relationship between remittances and economic development at the national level, there has been little research conducted at the household level. This may be due to several

Figure 2.1: International Remittance that Vietnam Received (per person in VND) and the number of Vietnamese workers overseas from 2000 to 2018 (WB, Vietnam Department of Labor, Invalids and Social Affairs)



factors. First, it is challenging to accurately measure the poverty level, especially in developing countries. The second challenge comes from the limitations and availability of data on remittances, employment, and migration at the household level. Navigating through these difficulties, this paper aims to study the impact of remittances on Vietnamese households. The study utilizes the Vietnamese Household Living Standard Survey which contains information on households' income, employment, and other key characteristics such as age, education level, and marital status.

The paper is organized as below. Section 2 lists an overview of the literature on international remittance and poverty reduction in developing countries. Section 3 provides the information about the Vietnamese Household Living Standard Surveys and its key variables. In Section 4, the econometric methodology and approaches that are used to estimate the impact of remittance on poverty is presented. Section 5 proposes our findings. The final section of the paper, Section 6, gives an overview of our conclusion and policy implication.

2.3 Literature Review

In the field of development economics, the views of remittances regarding its impacts on migration and poverty reduction in home country are positive. (Adams, 1991) studies the impact of remittances on rural Egypt using the dataset of 1,000 households from 1968-1986. Among 339 households that had someone working abroad in neighboring countries, such as Iraq, Kuwait, Libya, or Saudi Arabia, the paper notes that on average, remittances account for 30.4 percent of total households' gross incomes. Further examinaion, the study concludes that with the help of remittance, the poverty rate of Egypt falls by 9.8 percent.

Consistent with this trend, Adams and Page (2005) examines 71 low- and middle-income developing countries, focusing on key variables such as international migration, remittances, inequality, and poverty. Their finding suggests that a 10 percent increase in international remittances is associated with a 2.1 percent reduction in individuals living under the poverty threshold of $1.00 per day. When controlling for potential endogeneity in remittances using instrumental variables, the impact is magnified, revealing that a 10 percent rise in international remittances correlates with a more substantial 3.5 percent reduction in poverty. Moreover, when translated into changes in households' mean income, a $1 U.S. dollar increase in mean income is linked to a 0.98 percent decrease in the poverty headcount.

In contrast, Lipton (1980), utilizing Census data from low-developing countries between 1951 and 1971, observes that remittances contribute to increased intra-rural inequalities. Lipton argues that better-off villagers are often ”pulled” towards more favorable opportunities, such as employment in firms, while those less fortunate are ”pushed” towards poverty and jobs with labor-replacing characteristics in the future. Likewise, Stahl (1982) proposes a similar perspective, contending that wealthier households stand to benefit more from migration, especially from international migration, compared to their less affluent counterparts.

In the context of Vietnam, a study based on the 1993 Vietnamese Living Standard Survey by Dang et al. (2003) indicates that remittances serve as crucial income sources for numerous rural households. They play an essential role in covering living expenses, paying utility bills, and supporting educational costs for family members staying home. In addition, Viet (2008) analyzes the Vietnamese Household Living Standard Survey (VHLSS) from 2002 to 2004 and suggests that foreign remittances contribute to a 2-percentage-point reduction in the poverty headcount.

The distinctive contribution of our study lies in its examination of the impact of international remittances over an extended timeframe, spanning from 2004 to 2016. In addition, unlike previous studies, our approach involves the separate measurement of the impact of domestic and international remittances. This allows for a more refined understanding of the varied effects of different types of remittances on household welfare and poverty reduction.

2.4 Data

The Vietnamese Household Living Standard Survey (VHLSS) was constructed by the World Bank in 1993 and 1998. Since 2002, the longitudinal survey is conducted every 2 years by the Vietnam General Statistical Office (GSO) with the assistance of the World Bank. The goals of the survey are to systematically monitor the living standard of Vietnamese households, evaluate and assess the Comprehensive Poverty Alleviation and Growth Strategy, and the Millennium Development Goals and Socio-Economic Development Goals by the World Health Organization.

Each survey consists of more than 30,000 households on 10 sections, including housing, income, expenditure, health, and education. For the expenditure section, only 9,000 households are randomly chosen to conduct the interview. The interviewed households were collected randomly and representatives from both rural areas, and cities.

Table 1 presents the proportions of households receiving remittances, both domestic and overseas, over the period 2004 to 2016. Notably, there is a discernible downward trend in the share of households receiving remittances, irrespective of their origin—domestic or overseas.

Table 2.1: Percentage of Households in VHLSS 2002 - 2016

	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Received no remittances	12.1	10.8	13.3	15.9	14.9	17.0	17.2
Received domestic only	87.3	85.1	82.9	84.1	82.1	81.6	81.6
Received oversea only	6.5	5.3	3.6	4.2	3.6	3.4	3.4
Received both	4.9	3.7	2.5	3.0	2.6	2.2	2.2

Table 2 offers insights into household characteristics during the same period.

Overall, there is a marginal shift in the gender composition of household heads, with a slight increase from 52% to 53% in favor of male-dominated households. Notably, there is an upward trajectory in the mean age of household heads, educational attainment, and annual income. Households that receive remittances, particularly from overseas, exhibit a higher level of education, and higher mean annual income (in Vietnamese dong). Looking at the household size, a general decreasing trend is observed across all households. However, those receiving overseas remittances tend to have a higher mean household size, except for 2008 and 2016.

Measuring remittances as a percentage of mean annual income, households receiving overseas remittances show an upward trend, increasing from 29.5% in 2004 to 44.2% in 2016. This indicates a growing significance of overseas remittances relative to the overall income of recipient households over the studied period.

Table 2.2: Household Characteristics in VHLSS 2004 - 2016

	2004	2006	2008	2010	2012	2014	2016
Gender of the head (male headed = 1)							
All	0.52	0.49	0.52	0.53	0.52	0.53	0.53
Received domestic remittances	0.51	0.49	0.51	0.53	0.52	0.52	0.52
Received oversea remittances	0.51	0.50	0.52	0.50	0.52	0.54	0.53
Mean age of household head (years)							
All	38.87	40.32	39.81	39.25	40.93	42.02	43.53
Received domestic remittances	39.31	40.78	40.05	39.54	41.46	42.65	44.19
Received oversea remittances	39.36	41.22	41.14	41.71	42.62	44.92	44.99
Mean household size							
All	4.00	3.86	3.91	3.72	3.79	3.69	3.56
Received domestic remittances	3.96	3.79	3.88	3.68	3.75	3.62	3.51
Received oversea remittances	4.11	3.97	3.84	3.81	4.06	3.64	3.50
Mean level of education (years)							
All	6.70	7.00	7.21	8.03	7.63	7.98	8.14
Received domestic remittances	6.72	6.9	7.11	8.00	7.61	7.98	8.14
Received oversea remittances	8.20	7.69	8.02	8.16	8.22	8.51	9.20
Mean household annual income (VND)							
All	24,621	32,537	47,367	66,790	92,627	107,642	126,864
Received domestic remittances	24,470	31,896	45,273	66,366	92,812	108,118	126,466
Received oversea remittances	48,715	47,928	65,401	100,888	142,751	135,600	166,547
Mean remittances as percent of mean annual income (%)							
All	10.41	12.24	9.30	1.876	1.72	1.28	1.51
Received domestic remittances	11.74	13.40	10.43	1.631	1.34	1.21	1.17
Received oversea remittances	29.46	36.93	28.05	51.5	41.83	35.57	44.20

2.5 The Model

In modeling the impact of remittances on household welfare, our approach involves estimating how remittances influence the probability of a household being in poverty. This methodology, as employed by Grootaert (1997) and more recently by Gyimah-Brempong and Asiedu (2009), assumes that the probability of a household being under the poverty threshold (y^*) depends on the likelihood of whether that household receives remittance and other key characteristics denoted as X.

The model incorporates key variables, including the age of the household head (age), the total number of members in household (hhsize), whether the gender of the household head is male or not (male), (male), whether the household was currently residing in rural area or not (rural), the marital status of the household (married, widowed, divorced, separated), the industry of the household head's occupation (agricultural and forest, industry and construction, or service sectors), and the geographic region of the household (Red River Delta, North-east, North-west, North Central, Southern Central Coast, Central Highland, South-east, and Mekong River Delta). Additionally, we also control for the ethnicity and years of education of the household head. To further refine our analysis, the remittance variable is segmented into domestic remittance (domes) and international remittance (abroad).

The model to test the specific impact of remittance vis-à-vis other key households' characteristics that contribute to the households' well-being takes the following form:

$$y^* = \alpha_0 + \alpha_1 X_{it} + \beta W_{it} + \epsilon_{it} \tag{1}$$

where y^* is a binary variable that indicates whether the household being under poverty (y^* =1); X is denoted as whether the household receives remittances; and W represents households' key characteristics; and i and t represent households and the year of survey, respectively.

The latent y^* variable is not observable, and binary. In other words, we are only able to observe whether the household is under poverty or not. Therefore, the value of the latent variable takes the following values:

$$\begin{cases} y & = 1, y^* > 1, and \\ y & = 0, otherwise \end{cases}$$

given that:

$$Prob(y = 1) = Prob(\epsilon > -\alpha_1 X_{it} + \beta W_{it}) = 1 - F(-\alpha_1 X_{it} + \beta W_{it}) \tag{2}$$

where F is a cumulative probability function. In the probit function form:

$$Prob(Under\_poverty = 1) = \alpha_1 X_{it} + \beta W_{it} + \epsilon_{it} \tag{3}$$

The equation we use for the estimation is:

$$\begin{aligned} Prob(Under\_poverty = 1) = \alpha_1 Domes_{it} + \alpha_2 Abroad_{it} + \alpha_3 Age_{it} + \alpha_4 Agesq_{it} + \\ \alpha_5 HHsize_{it} + \alpha_6 Male_{it} + \alpha_7 Ethic_{it} + \alpha_8 Rural_{it} + \alpha_9 YrsEdu_{it} + \alpha_{10} Region_{it} \\ + \alpha_{11} Industry_{it} + \alpha_{12} MaritalStatus_{it} + \alpha_{13} Gender * Abroad_{it} + \alpha_{14} Year_t + \epsilon_{it} \end{aligned} \tag{4}$$

with ϵ_{it} as the stochastic error term, and other variables are defined as above.

The interaction variable between gender and international remittance is used to measure the difference impact between the gender of the household head and the probability of the household receiving oversea remittance, while holding other variables constant.

Table 2.3: Variable Names and Expected Signs

Variable	Descriptive	Expected	Mean
abroad	= 1 if the household receives international remittance at year t	-	0.046
domes	= 1 if the household receives domestic remittance at year t	-	0.843
age	age of the head of the household	-	40.74
hhsize	total number of members in household	+	3.79
male	=1 if the gender of the household head is male	-	0.52
rural	=1 if household is currently residing in rural area at year t	+	0.76
ethic	= 1 if household is Kinh (majority)	+	0.81
genabr	interaction vairable between gender and international remittance	+	-

2.6 The Estimation Method:

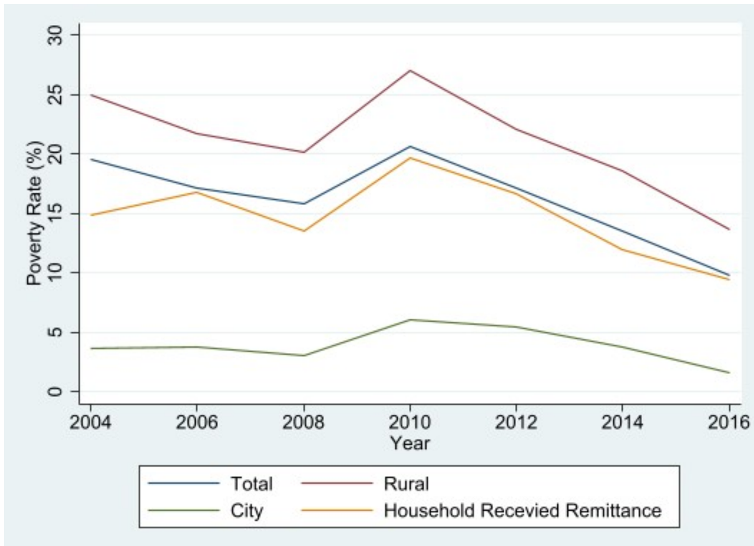
For this paper, we use different methodologies to estimate the model, including Ordinary Least Square (OLS), Logit model, and Probit model, assuming a normal distribution of the error term. For the project, the dependent variable (Under Poverty) is binary. In addition, our main regressor, the international remittance (abroad) is also binary and likely endogenous. Following the approach suggested by Carrasco (2001), we propose a reduced form probit equation for remit:

$$remit_{it} = I(remit^{*}_{it} > 0) = I(\lambda_0 + \lambda_1 X + \lambda_2 W_{it} + \epsilon_{it} > 0) \qquad (5)$$

with ϵ is the error term and is normally distributed.

To address the endogeneity of the remittance variable, we use instrumental variables in the remittance equation that may affect the rate of remittance, but do not directly impact the probability of a household being in poverty. In this estimation, the total annual rainfall level serves as the instrument for the likelihood of receiving remittances from abroad. The total annual rainfall is measured for each region of Vietnam and each observed year. Elevated rainfall in a given year is

Figure 2.2: Poverty rate over the period of 2004-2016



likely to impact agriculture and other services, prompting migrants to send more money to assist their families in their hometowns. The instruments adhere to the principles of relevance and exogeneity as outlined by Sasin and McKenzie (2007). Before employing the bivariate probit model, we run several statistical tests to ensure the validity of the instrument.

In Figure 2.2, the poverty line for each year from 2004 to 2016 is derived from the VHLSS data. Utilizing the aggregate household expenditure per year, a household is categorized as under poverty if its total expenditure falls below the established standard poverty line, which is defined by the General Statistics Office (GSO) and the World Bank. This standard poverty line represents the aggregate expenditure necessary to meet basic nutritional requirements and cover other essential non-food needs, including clothing and shelter.

2.7 Results

The results obtained through the OLS, logit, and probit models are presented in Table 4. The first column shows the estimates from OLS method. While the OLS method yields results with the same directional impact, there are variations in magnitudes comparing to the logit and probit approaches. For example, for variables such as age and household size, the OLS approach tends to overestimate their impacts on the probability of being under poverty. Conversely, the OLS approach underestimates the impact of overseas remittances while overestimating the impact of domestic remittances.

When comparing the logit and probit approaches, both provide similar estimates and directions. Importantly, both domestic and overseas remittances are deemed statistically significant in influencing the probability of a household being in poverty.

Table 2.4: Marginal Effect of Remittances on Poverty

	(1) OLS	(2) Logit	(3) Probit	(4) Probit-w-Interact
Received Domestic	-0.0258***	-0.0216***	-0.0224***	-0.0216***
	(0.00380)	(0.00357)	(0.00361)	(0.00363)
Received Abroad	-0.0678***	-0.118***	-0.111***	-0.124***
	(0.0066)	(0.0105)	(0.00928)	(0.0133)
Age	-0.00961***	-0.00850***	-0.00836***	-0.00891***
	(0.000463)	(0.000413)	(0.000418)	(0.000419)
HHsize	0.0213***	0.0179***	0.0180***	0.0166***
	(0.000894)	(0.000814)	(0.000828)	(0.000830)
Male	-0.0002	0.002	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)
Male HH-head	-0.000155	0.00221	0.00184	-0.00196
	(0.00282)	(0.00279)	(0.00278)	(0.00282)
Ethic group	0.228***	0.126***	0.134***	0.154***
	(0.00389)	(0.00295)	(0.00313)	(0.00297)
Living in rural	0.0634***	0.117***	0.109***	0.115***
	(0.00340)	(0.00486)	(0.00433)	(0.00436)
Yrs of educ	-0.0157***	-0.0156***	-0.0159***	-0.0138***
	(0.000401)	(0.000401)	(0.000404)	(0.000389)
Married	0.0197***	0.0193***	0.0165***	0.0193***
	(0.00405)	(0.00409)	(0.00403)	(0.00405)
Industry/Construct.n	-0.0740***	-0.0802***	-0.0766***	-0.0792***
	(0.00448)	(0.00461)	(0.00444)	(0.00445)
Service	-0.0199***	-0.0194***	-0.0190***	-0.0203***
	(0.00413)	(0.00456)	(0.00446)	(0.00448)
Northern area	-0.250***	-0.021***	-0.021***	-0.020***
	(0.004)	(0.004)	(0.004)	(0.004)
Southern area	-0.087***	-0.082***	-0.082***	-0.82***
	(0.004)	(0.004)	(0.004)	(0.004)
2006	0.006	0.009**	0.010**	0.010**
	(0.005)	(0.004)	(0.004)	(0.005)
2008	-0.021***	-0.192***	-0.017***	-0.017***
	(0.005)	(0.005)	(0.005)	(0.005)
2010	0.060***	0.072***	0.070***	0.070***
	(0.006)	(0.006)	(0.006)	(0.006)
2012	0.020***	0.025***	0.023***	0.023***
	(0.006)	(0.006)	(0.006)	(0.006)
2014	-0.006	-0.002	-0.004	-0.004
	(0.006)	(0.006)	(0.006)	(0.006)
2016	-0.028***	-0.030***	-0.032***	-0.031***
	(0.006)	(0.006)	(0.006)	(0.006)
Male*abroad				0.0134
				(0.0186)
N	57565	57565	57565	57565

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In column 3 of Table 4, the probit approach presents the marginal effects of both domestic and international remittances as negative and statistically significant, signaling that remittances exert a substantial impact on the probability of whether a household is under poverty or not. The average marginal effect on the probability of a household being in poverty associated with receiving remittances from abroad is a notable decrease of 11.1 percentage points. Similarly, the average marginal effect on the probability of a household being in poverty associated with receiving domestic remittances is a 2-percentage-point decrease.

Conversely, the marginal effects of household size, belonging to an ethnic group, and residing in rural areas are positive and statistically significant. This implies that households belonging to an ethnic group or residing in rural areas have a higher likelihood of being in poverty. For example, the average marginal effect on the probability of a household being in poverty associated with living in rural areas is a substantial 10.9 percentage point increase, or a 13.4 percentage point increase if the household head belongs to an ethnic group.

Furthermore, the marginal effects of education and age are negative and statistically significant. Specifically, for years of education, the average marginal effect on the probability of a household being in poverty associated with an additional year of education is a 1.60 percentage point decrease.

When comparing across sectors of household employment, the average marginal effect on the probability of a household being in poverty associated with the household head working in the industry and construction sector is a statistically significant 7.7 percentage point decrease. In contrast, it is only a 1.9 percentage point decrease if the household head works in the service sector.

When evaluating the impact of the gender of the recipient of international remittances, the marginal effect is positive but not statistically significant. This implies that the gender of the household head receiving international remittances has minimal to no discernible impact on the probability of the household being in poverty.

In Table 5, the first column presents the marginal effect of remittances on poverty using the probit approach and the amount of received remittance by households is categorized into quintiles . The results indicate that a household receiving domestic remittances is associated with a 2.2 percent decrease in the probability of being in poverty. For oversea remittances, the findings suggest that remittances from overseas significantly decrease the probability of being in poverty. Notably, the impact is more pronounced for the 4th and 5th quintiles, suggesting a more substantial effect of remittances on higher amounts.

In the second column, the regression includes two interaction terms: oversea remittance with the northern region and oversea remittance with the southern region. This model examines how the effect of receiving remittances from abroad on poverty varies by region. For example, if a household resides in the northern region, oversea remittances have a larger impact in reducing the probability of the household being in poverty by two percentage points. Furthermore, both interaction terms are statistically significant, indicating a region-specific effect of overseas remittances on poverty.

In Table 6, the impacts of domestic and international remittances are separately estimated using the probit method. Upon comparing the two models, they exhibit nearly identical estimates, and a more pronounced impact of international remittances is evident. The average marginal effect on the probability of a household being in poverty associated with receiving international remittances is a substantial 11.4 percentage point decrease, whereas it is only a 1.88 percentage point decrease for receiving domestic remittances. Consistent with previous estimations, the interaction variable between having a male as the head of the household and receiving overseas remittances is not statistically significant. Regarding the marginal effect of occupational choice, both models share similarities in estimates and directions, reinforcing the robustness of the findings across different specifications.

Table 2.5: Marginal Effect of Remittances on Poverty in Quintiles

	(1) Probit - Model	(2) Probit-w-Region Interactions
Age	-0.00829***	-0.00830***
	(0.000418)	(0.000418)
HHsize	0.0180***	0.0180***
	(0.000828)	(0.000828)
Male	0.002	0.002
	(0.003)	(0.003)
Ethic group	0.134***	0.134***
	(0.00312)	(0.00312)
Living in rural	0.109***	0.109***
	(0.00433)	(0.00433)
Yrs of educ	-0.0159***	-0.0159***
	(0.000404)	(0.000404)
Married	0.0163***	0.0164***
	(0.00402)	(0.00402)
Indust-Constrt	-0.0769***	-0.0769***
	(0.00443)	(0.00443)
Service	-0.0188***	-0.0190***
	(0.00446)	(0.00446)
Received Domes	**-0.0217*****	**-0.0219*****
	(0.00361)	(0.00361)
Abroad-2nd	**-0.0758*****	**-0.0471****
	(0.0201)	(0.0222)
Abroad-3rd	**-0.108*****	**-0.0815*****
	(0.0230)	(0.0250)
Abroad-4th+5th	**-0.234*****	**-0.202*****
	(0.0278)	(0.0305)
Received Abroad*Northern Region		-0.0596***
		(0.0187)
Received Abroad*Southern Region		-0.0424*
		(0.0219)
N	57565	57565

Standard errors in parentheses, * (p<0.10), ** (p<0.05), *** (p<0.01)

Table 2.6: Marginal Effect of Domestic and International Remittances on Poverty Using Probit and Bivariate Approaches

	(1) Domestic Only	(2) International Only	(3) Probit-IV
Age	-0.00840***	-0.00830***	-0.00948***
	(0.000419)	(0.000418)	(0.000539)
HHsize	0.0179***	0.0183***	0.0205***
	(0.000829)	(0.000828)	(0.00101)
Male	0.002	0.002	0.006
	(0.0028)	(0.0028)	(0.0034)
Ethic group	0.136***	0.136***	0.153***
	(0.00313)	(0.00312)	(0.00377)
Living in rural	0.111***	0.109***	0.137***
	(0.00433)	(0.00434)	(0.0138)
Yrs of educ	-0.0161***	-0.0159***	-0.0177***
	(0.000405)	(0.000404)	(0.000496)
Married	0.0164***	0.0161***	0.0147***
	(0.00403)	(0.00403)	(0.00529)
Widowed	0.0169**	0.0159**	0.0158**
	(0.00697)	(0.00696)	(0.00698)
Industry/Construct.n	-0.0778***	-0.0775***	-0.0841***
	(0.00445)	(0.00444)	(0.00572)
Service	-0.0202***	-0.0196***	-0.0158***
	(0.00448)	(0.00448)	(0.00551)
Male*abroad		0.0142	0.0412
		(0.0185)	(0.0669)
Received Domes	**-0.0188***		**-0.0321***
	(0.00360)		(0.00450)
Received Abroad		**-0.114***	**-0.148**
		(0.0133)	(0.0651)
N	57565	57565	57565

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

When combining both variables in the probit approach with instrumental variables — specifically, the total rainfall per year and the distance to the nearest bank, the results indicate that the average marginal effect on the probability of households being in poverty associated with receiving international remittances is a significant 14.1 percentage point decrease. Similarly, for receiving domestic remittances, the average marginal effect is a notable 3.2 percentage point decrease. This underscores the substantial impact of both international and domestic remittances in reducing the likelihood of households being in poverty when accounting for instrumental variables.

2.8 Conclusion

Utilizing data from the Vietnamese Household Living Standard Survey spanning from 2004 to 2016, this study employs different approaches, including probit and bivariate methods to assess the impact of international remittances on household poverty in Vietnam. Our findings reveal that remittances, especially remittances from oversea, significantly decrease the probability of a household being in poverty. These results align with the conclusions drawn by other researchers investigating the relationship between poverty and remittances in other developing countries.

Furthermore, our study highlights that the choice of occupation also plays a role in shaping the likelihood of a household being in poverty. Given the observed reduction in the probability of households being in poverty associated with international remittances, we recommend that policymakers in Vietnam actively encourage their overseas citizens to increase remittance flows to the country. Such measures can contribute to poverty reduction and socioeconomic well-being at the household level.

Furthermore, our investigation into household characteristics reveals that being a member of an ethnic group and/or residing in rural areas increases the probability of households being in poverty. Both variables exhibit statistical significance. This outcome underscores the need for policymakers to intensify their efforts, providing opportunities and financial assistance to alleviate the challenges faced by ethnic groups.

While the bivariate probit approach aligns with our expectations, we are eager to subject the model to re-examination and alternative estimations, such as pseudo-panel estimates. This approach involves creating a panel of cohorts and utilizing cohort means as individual estimates, aiming to eliminate errors correlated with regressors in any given year. This methodological variation can offer additional insights and enhance the robustness of our findings.

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Chapter 3

Tax Elasticity of Border Sales:
A Meta-analysis

3.1 Abstract

When nearby regions have different tax rates, residents may travel to shop in the lower tax rate region. The extent of this activity is captured by the tax elasticity of border sales (TEBS). We collect 749 estimates of TEBS reported in 60 studies, and conduct the first meta-analysis of this literature. We show that the literature is prone to selective reporting: positive estimates are systematically discarded. Sales of food, retail and fuel are more elastic compared to sales of tobacco and other individual 'sin' products. Cross-border shopping is more prominent in the US— compared to Europe and other countries.

3.2 Introduction

In countries with decentralized fiscal systems, jurisdictions have authority to determine their unique tax policies, adjusting tax rates to raise tax revenues or discourage consumption of certain products (e.g. cigarettes). But the desired outcomes of tax policy changes may be jeopardized when individuals respond by traveling to shop at a neighboring jurisdiction, taking advantage of tax differentials. When such cross-border shopping is prominent, an increase in, for example, a cigarette tax in a jurisdiction can result in more tax avoidance while having little effect on cigarette consumption or tax revenues.

There is a considerable literature within state and local public finance that studies the link between such cross-border sales and taxation, with many studies reporting estimates that can capture the elasticity of border sales to changes in tax rates, which we refer to as 'tax elasticity of border sales' (TEBS, for brevity). Examples of studies on cross-border sales and taxation are Tosun & Skidmore (2007), Goel & Nelson (2012), Chernick & Merriman (2013), Jansen & Jonker (2018), Hansen *et al.* (2020).[1] However, the reported estimates vary widely; they are also context specific, and it is not clear to what extent estimates pertaining to a tax change in one region can be used to understand the response to a different tax change in another region, at a different point in time. Yet, knowing TEBS is crucial for addressing a variety of theoretical and empirical questions in public finance and regional economics, from the behavioral response of individuals to taxation, to tax incidence and the impact of taxation on individuals' welfare.

We conduct the first meta-analysis of the literature estimating tax elasticity of border sales. Unlike previous studies in this field, we address and reconcile the diversity of results reported by the empirical literature estimating TEBS. First, we examine the sources of variation in TEBS estimates. We collect 749 estimates reported by 60 studies in the field. For each estimate we construct a comprehensive set of explanatory

[1] Tosun & Skidmore (2007) use data on food sales and sales tax rates for West Virginia counties to estimate TEBS over the 1988-1991 period. Chernick & Merriman (2013) study the response of cross-border cigarette sales in New York City before and after New York State raised its cigarette tax rate in June 2008. Jansen & Jonker (2018) examine the responses of Dutch drivers to the variation in cross-border fuel price differences. Hansen *et al.* (2020) study the cross-border sales of marijuana along the Washington-Oregon border.

variables detailing features of the underlying data and methodology employed. We then use meta-regressions to pin down sources of systematic variation in estimates, addressing model uncertainty with Bayesian Model Averaging. Meta-regressions have previously been used to detect systematic patterns in estimates produced by a number of empirical literatures, examining the effects of minimum wage on employment (Card & Krueger 1995, Doucouliagos & Stanley 2009), of distance on trade (Disdier & Head 2008), of IMF programs on growth (Balima & Sokolova 2021); literatures that study elasticities of labor supply (e.g. Chetty *et al.* 2013), monopsony in labor markets (Sokolova & Sorensen 2021) the effects of active labor market programs (Card *et al.* 2017), etc.

Second, we investigate publication bias in the literature estimating TEBS, the bias that has previously been found to be prominent in many fields of economics research, see e.g. Card & Krueger (1995), Stanley (2001), Brodeur *et al.* (2016), Ioannidis *et al.* (2017), Sokolova & Sorensen (2021). Third, we use the results of the meta-regression analysis to construct fitted estimates of TEBS for different categories of goods and geographic regions, corrected for the selective reporting in the literature.

The mean TEBS reported in the literature is -0.57, suggesting that cross-border shopping should have a non-negligible effect on sales at the border. However, we show that, like many other literatures in economics, the literature estimating TEBS is prone to selective reporting of the results. Specifically, studies tend to underreport results with a positive sign: such results are counter-intuitive as they are not in line with the economic theory. Yet, given the randomness of the data, counter-intuitive results should still appear from time to time. This underreporting leads to the asymmetry in the distribution of reported TEBS estimates, with the mean reported estimate being biased away from the 'true' effect. We construct a corrected mean effect—a task that can only be accomplished within the framework of a meta-analysis. We find that the corrected effect is somewhat less prominent: most of our specifications find it to be between -0.4 and -0.5, some indicate it may be even smaller in magnitude.

We also find that TEBS estimates vary systematically with the category of goods considered. Cross-border sales of food and retail, which have a broad tax base, are found to be much more elastic compared to sales of tobacco: the absolute value of TEBS for food and retail exceed that of tobacco by about 2. Food and retail comprise a large fraction of household budget, and increases in sales taxes may strongly affect overall household expenses—more so, compared to an increase in an excise tax on one product.[2] Thus, traveling to save on food and retail may be more economically justified compared to traveling to save on tobacco. Compared to tobacco, fuel sales are also found to be more elastic: with TEBS greater in absolute value by about 0.7-0.8. Gas stations tend to display fuel prices at their entrances in a way that eases cross-jurisdiction comparisons by travelers passing by, thus possibly encouraging cross-border shopping. By contrast, TEBS of tobacco does not appear to differ from TEBS of other individual 'sin' products, such as marijuana, alcohol and soda. Finally, while cross-border sales appear very elastic for the US where 'car culture' is prevalent, the cross-border effect is much less prominent in Europe and other countries.

Our study is also related to the literature examining the question of "who (ultimately) bears the burden of taxation in a jurisdiction?" To the extent that there

[2]Of course, we acknowledge the fact that sales of food (specifically grocery sales) are exempt from taxation in a majority of states in the US. According to Federation of Tax Administrators (FTA), there are 16 states that tax food to some extent, see taxadmin.org. We should also note that there is no exemption for retail sales aside from short periods of sales tax holidays.

is cross-border shopping, some of the tax burden will be shared between individuals in different jurisdictions—this shifting of the tax burden from one jurisdiction to another is addressed by the literature on tax incidence (e.g. McLure 1967, Hogan & Shelton 1973, Mutti & Morgan 1983, Fujii *et al.* 1985, Gade & Adkins 1990, Pollock 1991, Morgan *et al.* 1996, Murray 2006, Khan *et al.* 2020, Minnesota Department of Revenue Tax Research Division 2021). Cross-border sales of different commodities have been seen as a direct way in which tax exporting occurs, and knowing TEBS is pertinent for assessing the magnitude of the corresponding effect. In a similar vein, the assumptions made about the elasticity of cross-border sales affect the results reported by a broader set of studies in public finance and regional economics (e.g. Trandel 1992, Nechyba 1996, Poterba 1996, Beard *et al.* 1997, Besley & Rosen 1999, Ohsawa 1999, and Nelson 2002).[3] Our fitted estimates of TEBS can serve as a reference for these literatures.

The fitted estimates of TEBS reported in this study can also be helpful to state and local policymakers as they contemplate tax changes in their jurisdiction. On the one hand, having accurate TEBS estimates is essential when assessing the stability and adequacy of tax revenues—a crucial task for jurisdictions with balanced budget requirements. For example, taxes on cigarettes and other tobacco products are usually earmarked for health and/or education programs. Cross-border sales can jeopardize the stability of those tax revenues and may in turn affect the expenditures financed by earmarked revenues. On the other hand, aside from the tax revenue concerns, cross-border shopping can undermine the outcomes of Pigouvian taxation. Excise taxes

[3] Additionally, there are also policy oriented (mostly non-academic) studies from the U.S. that provide economic and fiscal impact of tax policy changes with a focus on state and local governments.

on cigarettes, alcohol, gasoline and marijuana are partially aimed at correcting the negative consumption externalities. If TEBS is high, an increase in cigarette tax does not necessarily mean that more people quit smoking, as they may continue to buy cigarettes from a lower-tax jurisdiction nearby. Interjurisdictional tax rate differences, including those that are due to recent sales tax holidays which aim at providing relief to families impacted by price increases, continue to generate incentives for cross-border shopping.[4] Knowing TEBS is important when evaluating the effects of such policies; the estimates provided here can help policymakers gauge the magnitude of TEBS suggested by the relevant literature.

3.3 Data Collection Strategy

3.3.1 Approaches to estimating TEBS

Studies examining cross-border sales typically estimate the responsiveness of sales at the border in one jurisdiction to changes in relative price between the jurisdiction under consideration and its neighbor—where the neighbor may have a different tax rate or even a different tax structure. The estimates are usually presented in the form of tax elasticity, or other formats from which the elasticity can be deduced. Due to lack of a name that is commonly used in this literature, we term such estimates 'tax elasticity of border sales', or TEBS.

[4]Federation of Tax Administrators provide information on state sales tax holidays www.taxadmin.org/sales-tax-holidays. Tax amnesties may also create tax differences between states and lead to revenue impacts as shown by Alm *et al.* (1990), Alm & Beck (1991), Alm & Beck (1993), Luitel & Sobel (2007), and Luitel & Tosun (2014) among others.

Studies can estimate TEBS with a version of the following regression model:

$$\ln Sales_{it} = \epsilon \cdot \ln P_{it} + \sum_{l=1}^{M} \beta_l Z_{l,it} + C_i + T_t + u_{ij}, \tag{1}$$

where $Sales_{it}$ are per capita sales of taxable items (e.g. general sales, food) at the border in region i (e.g. county) at time t; $Z_{l,it}$ are controls that capture the overall demand in region i (e.g. log per capita income); C_i and T_t are region- and time-specific effects and u_{ij} is the disturbance term (see e.g. Tosun & Skidmore 2007). The variable P_{it} captures the after-tax price of taxable goods of interest in region i relative to the neighboring region:

$$P_{it} = \frac{P_{it}^H (1 + \tau_{it}^H)}{P_{it}^N (1 + \tau_{it}^N)}, \tag{2}$$

where P_{it}^H and τ_{it}^H are the before-tax price and tax rate in the home region i, and P_{it}^N and τ_{it}^N are the before-tax price and tax rate in the neighboring region (see e.g. Walsh & Jones 1988, Wooster & Lehner 2010). The parameter ϵ in (1) captures a percentage change in sales that would occur if the relative price P_{it} increases by 1%—i.e. TEBS.

Studies differ in their choices over model specifications used to estimate ϵ. A number of studies make a simplifying assumption that the before-tax prices at home and in the neighboring region are the same, i.e. $P_{it}^H = P_{it}^N$ (e.g. Goolsbee *et al.* 2010). Under this assumption it is enough to consider the difference between tax rates at home and in the neighboring region to capture ϵ, TEBS. Studies estimating regression (1) make an implicit assumption that border sales respond symmetrically to a 1% increase in after-tax prices at home and a 1% decrease in prices of the neighbor; in other studies this assumption is relaxed, and the coefficient on the log of after-tax home price is allowed to differ from that on the after-tax neighbor price, as $\ln[P_{it}^H(1+\tau_{it}^H)]$ and $\ln[P_{it}^N(1+\tau_{it}^N)]$ enter separately into regression (1), e.g. Goel (2008), Connelly *et al.* (2009), and Goel & Nelson (2012). In such regression models, the coefficient pertaining to the after-tax neighbor price can be interpreted similarly to ϵ under the assumption that the after-tax price in the home region is constant. We collect estimates coming from all specifications discussed above, but introduce controls to capture these subtle differences in their interpretation.

The majority of studies in our sample define border regions in a binary way (e.g. a county is either a 'border' county or not), without differentiating between areas that might be closer or further from the border. The TEBS estimates obtained in these studies can be thought of as elasticities conditional on mean distance from the border examined by this literature. At the same time, a fraction of studies in this literature considers interactions between sales and distance from the border (e.g. Asplund *et al.* 2007). To make these estimates comparable with the rest, we use reported results to construct implied estimates of TEBS conditional on mean distance considered in the paper. We use controls to mark cases in which such approximations were performed.

Finally, a number of studies construct experiments to directly measure changes in border sales in response to tax innovations by e.g. collecting discarded cigarette packs in a given location and calculating the percentages of packs purchased locally before and after a tax change (see Merriman 2010, Chernick & Merriman 2013). For these studies we approximate ϵ by 1) collecting the provided estimate of the percentage change in sales, $\Delta Sales/Sales$, 2) computing the percentage change in the relative prices $\Delta P/P$ from the information provided in the study and 3) setting

$\epsilon = (\Delta Sales/Sales)/(\Delta P/P)$ and approximating the standard error with the delta method.

3.3.2 Data collection and inclusion criteria

We use Google Scholar to search for the studies estimating TEBS. We implement a search query containing the words 'relative price', 'tax difference elasticity estimate border', 'cross-border', 'neighboring sales', 'tax', 'shopping', 'purchases', and 'estimates' and save the search results on April 30th, 2021. We read through abstracts of papers appearing on the first 50 pages, download and save papers that seem to report relevant results. We then read through the downloaded papers making sure they contain estimates of TEBS, or results that could be used to derive the implied TEBS estimates, implementing additional conversions discussed in the previous subsection. We also require the studies to report some measures of statistical significance of each estimate (i.e. standard errors, t-statistics or p-values). We also examine the references of the articles we find to locate any research papers that our search procedure may have missed.

We include papers published in peer-reviewed journals: these papers would have gone through the peer-review process and therefore have passed a quality check. We also include working papers that came out after the year 2018, as for these more recent works the lack of publication does not imply anything about the papers' quality or relevance.

This search strategy yielded 60 studies providing 749 estimates.[5] For each esti-

[5] The full list of studies in our sample can be found in Appendix 3D.

mate, we record its corresponding standard error and detail the context in which the estimate was obtained (e.g. product type, empirical methodology, geographic location, etc.). These estimates cover a diverse set of geographic regions and product groups. We report the sample statistics in Table 3.1.

Table 3.1: Estimates of TEBS

	Mean	Median	5%	95%	N	N Stud.
All	-0.57	-0.19	-2.20	0.23	749	60
Product groups						
Food & Retail	-1.79	-0.67	-7.77	0.12	94	10
Fuel	-0.26	-0.06	-1.50	0.40	88	6
Tobacco	-0.43	-0.20	-1.55	0.16	485	35
Other 'sin' products	-0.33	-0.04	-2.20	0.70	82	10
Regions						
U.S.	-0.59	-0.19	-2.33	0.20	584	50
E.U. & other countries	-0.48	-0.21	-2.08	0.23	165	12

Notes: 5% and 95% refer to the corresponding percentiles.

The mean estimate of TEBS is -0.57, but estimates vary widely. Estimates of TEBS seem to differ depending on the types of sales considered, with the most prominent mean elasticity of -1.79 observed for food and retail purchases, and somewhat smaller results for fuel (-0.26), tobacco (-0.43) and other 'sin' products, such as marijuana, alcohol and soda (-0.33 overall). US sales appear to be more responsive to tax changes compared to sales in Europe and other countries (with mean elasticity of -0.59 compared to -0.48).

The observed variation in estimates may be due to fundamental differences between the cross border effects for different groups of goods. At the same time, it is possible that, coincidentally, studies estimating cross-border effects e.g. for food and retail tend to use empirical methods and data that are markedly different from those employed to estimate TEBS for other goods. To disentangle sources of variation in estimates we therefore need to carefully consider features of each studies' design. Furthermore, it is possible that mean reported estimates are affected by preferences of the authors working in TEBS literature—in other words, that the literature is prone to some selective reporting of the results. In the subsequent sections we will evaluate these alternative explanations for observed variation in TEBS and distinguish between its sources.

3.4 Publication bias

Estimates of TEBS reported by the literature may be affected not only by fundamental features of the underlying data and studies' design, but also by practices surrounding the publication process and preferences of the profession. Brodeur *et al.* (2016) examine 50,000 tests for empirical significance published in top three journals in economics and conclude that authors tend to under-report results with p-values between 0.25 and 0.10, possibly due to them engaging in specification searches to obtain results that are statistically significant. Card & Krueger (1995) and Doucouliagos & Stanley (2009) document publication selection bias in the literature studying the effect of minimum wage increases on employment; they find that, even though a large fraction of the literature reports a strong negative effect, this effect disappears once publication bias is accounted for. In a similar vein, Havranek & Sokolova (2020) find that the mean reported estimates of shares of rule-of-thumb consumers exhibit strong upward bias due to systematic discarding of negative results. Sokolova & Sorensen

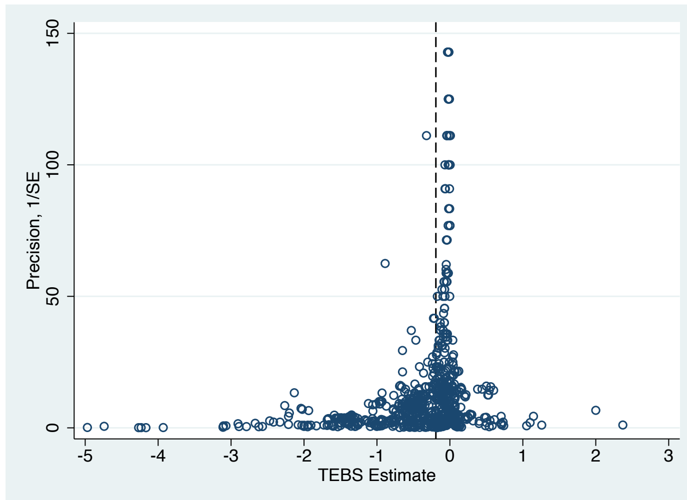
(2021) document a similar bias in the literature estimating monopsony power on the labor market. Ioannidis *et al.* (2017) argue that about 80% of the findings reported in economics literatures are exaggerated and single out meta-analysis as a tool for correcting such biases.

The reported estimates of TEBS may also be prone to publication selection bias. Consider the following thought experiment. Suppose that in line with the economic theory the underlying 'true' elasticity is negative, but that it is also relatively close to zero, i.e. the magnitude of the effect is small. Estimating this parameter on noisy data using standard unconstrained estimators should yield a symmetric distribution of estimates that is centered around the 'true' underlying parameter.

Because (by assumption) the 'true' effect is relatively close to zero, a fraction of estimates with low precision ends up positive. Suppose that because a positive TEBS has no good theoretical interpretations researchers obtaining positive results engage in further specification searches until the estimates become negative. If a large fraction of positive estimates is thus discarded, the distribution of estimates that are being reported by researchers would become skewed. This type of selective reporting would make it difficult for researchers to assess the underlying 'true' TEBS, as the mean estimate reported by the literature would exhibit a downward bias.

We now turn to investigate whether the literature on TEBS is affected by selective reporting of the estimates. The intuition behind testing for publication bias can be summarized as follows. Absent selective reporting, estimates found in empirical literature should be distributed symmetrically around the 'true' underlying effect—provided that the estimates can be thought of as assessing the same underly-

Figure 3.1: Funnel Plot



Notes: The figure plots TEBS estimates from our dataset against the reported precision; the dashed line indicates sample mean. The figure is truncated at $1/SE = 150$.

ing parameter.[6] A skewed distribution of reported estimates would signal that certain results are being systematically discarded.

Figure 3.1 depicts TEBS estimates in our sample; the estimates are plotted against their precision ($1/Standard\ error$). In the absence of selective reporting, this funnel plot should be symmetrical, with more precise estimates clustering around the underlying 'true' effect (see Egger *et al.* 1997). In our sample, the most precise estimates lie close to zero, signaling that the 'true' underlying effect may be small in magnitude. At the same time, the left tail of the funnel appears to be much more prominent compared to the right tail. This could mean that the positive estimates are being systematically discarded, which would imply that the mean estimate reported in Table 3.1 exhibits a downward bias.

[6]We will later allow for systematic variation in the 'true' TEBS across studies.

We will now conduct a formal funnel asymmetry test (see Stanley 2005). Estimation methods commonly used by researchers assume the ratio of the estimate to its standard error to be symmetrically distributed (e.g. t-distributed). If this assumption holds, the estimates should not be correlated with their standard errors. We will test this by regressing the estimates in our sample on their standard errors:

$$\hat{\epsilon}_{ij} = \epsilon_0 + \gamma \cdot SE(\hat{\epsilon}_{ij}) + u_{ij}, \tag{3}$$

where $\hat{\epsilon}_{ij}$ is the i-th estimate of TEBS reported by j-th study, $SE(\hat{\epsilon}_{ij})$ is its standard error, and u_{ij} is noise. Absent publication bias, the coefficient γ should be zero; if authors systematically discard positive results, this coefficient would be negative. Importantly, the estimate of the constant term ϵ_0 can be interpreted as an approximation of the unbiased effect (Stanley 2008 shows this approximation to perform well in Monte Carlo simulations). We will use estimates of ϵ_0 to construct a correction for the effect of publication bias.

The first column of Table 3.2 shows OLS estimates of model (3). We cluster the standard errors at the study level to address possible within-study correlation in estimates. The coefficient on the standard error is negative and statistically significant: as discussed above, this suggests selective reporting of the negative estimates. The constant term ϵ_0 is estimated at -0.4, giving the approximate 'true' unbiased effect. This effect is less pronounced when compared with the sample mean of -0.57, suggesting that the presence of publication selection bias leads to an exaggerated mean reported TEBS—in absolute value. Thus, once the publication bias is accounted for, the cross-border trade effect reported by the literature becomes somewhat more modest.

Next, it is possible that estimates are affected by the unobserved study-level characteristics; we therefore evaluate a specification featuring study-level fixed effects, as is done in e.g. Havranek 2015, Sokolova & Sorensen 2021—see Table 3.2, column 'FE'. Studies often report multitudes of estimates, some of which may be inferior to others. We next evaluate a specification in which we estimate γ and ϵ_0 using only the variation across studies (see e.g. Havranek & Sokolova 2020); we report the results under 'BE' in Table 3.2. To address the potential heteroscedasticity and give more weight to more precise estimates, we also evaluate a specification in which each estimate is weighted by its precision, as recommended in Stanley & Doucouliagos (2015) (see 'Precision' in Table 3.2). Finally, some studies report many more estimates compared to others. To give studies roughly equal weight, we assess a specification in which each estimate is weighted by the inverse of the number of estimates reported in the associated study (as is done in e.g. Gunby *et al.* 2017, Havranek & Sokolova 2020); these results appear under 'Study' in Table 3.2.

Table 3.2: Testing for Publication Bias

	OLS	FE	BE	Precision	Study
SE	-0.315	-0.306	-0.687	-0.998	-0.730
	(0.113)	(0.083)	(0.179)	(0.333)	(0.330)
Constant	-0.400	-0.405	-0.504	-0.034	-0.511
	(0.095)	(0.045)	(0.258)	(0.015)	(0.211)
Studies	60	60	60	60	60
Observations	749	749	60	749	749

Notes: Standard errors appearing in parenthesis are clustered at the study level. *FE*=specification with study-level fixed effects; *BE*=specification that uses median estimates and standard errors for each study; *Precision*=specification in which each estimate is weighted by its precision; *Study*=specification in which each estimate is weighted by the inverse of the number of estimates reported in the associated study.

In all specifications listed above there is a statistically significant correlation between the reported estimates and their standard errors—this, again, suggests that the literature on TEBS is prone to selective reporting of the results. The constant term (that can be interpreted as the bias-corrected effect) is negative and statistically different from zero; its magnitude is smaller compared to the sample mean of -0.57, particularly in the specification that employs precision weights. Thus, there is evidence of a statistically significant TEBS even when publication bias is accounted for, albeit the bias-corrected effect is less prominent compared to the mean estimate of -0.57 reported by the literature.

While the evidence of selective reporting uncovered thus far appears strong, it is possible that some of it is driven by outliers in the data: a small group of very imprecise negative estimates could contribute to the observed negative association between estimates and their standard errors. We investigate this possibility by repeating the exercise of Table 3.2 for samples of estimates subject to a number of outlier treatments. Specifically, we consider the samples with outliers winsorized at 1% and 5% (.5% and 2.5% in each tail), and with 1% and 5% of outliers dropped—see Table 3B.1. The results appear largely unaffected by the treatment of outliers.

Another caveat of the strategy outlined above is that it does not, technically, allow to distinguish between forms of selective reporting (e.g. selection for the ‘right sign’, or selection for statistical significance). In a recent work, Andrews & Kasy (2019) propose an alternative strategy for testing for publication bias, which involves explicit modeling of the publication selection process. The approach developed by Andrews & Kasy (2019) models probability of a result being reported as a step function of the associated Z-score; the reporting probabilities may differ between negative significant results (Z-score below -1.96), negative insignificant results (Z-score between -1.96 and 0), positive insignificant results (Z-score between 0 and 1.96) and positive significant results (Z-score over 1.96). Furthermore, the approach developed by Andrews & Kasy (2019) allows calculating the unbiased underlying mean effect. Previously, this method has been implemented in a similar context by Sokolova & Sorensen (2021).

We discuss this technique in Appendix 3B and apply it to our estimates. We find prominent evidence of selection for the 'right' sign, as positive estimates tend to be 18 times less likely to be reported compared to estimates that are negative and significant. The probability of reporting of negative insignificant estimates is about 7 times smaller compared to that of negative significant results. The bias-corrected effect is found to be very close to zero.

One remaining caveat pertaining to both the funnel asymmetry test and the Andrews & Kasy (2019) approach is that they rely on the assumption of independence between the estimates produced by latent studies and their standard errors. However, it is possible that some choices that researchers make that determine studies' design would affect the estimate and the standard error in the same direction. We remedy this using two strategies. First, we consider relatively homogenous subsamples of estimates that are more likely to pertain to the same 'true' underlying values of TEBS: the subsample of estimates characterizing TEBS for tobacco purchases only, and the subsample of estimates obtained using OLS. We repeat the exercises of Figure 3.1 and Table 3.2 for these two subsamples and report the results in Figure 3B.1 and Table 3B.2.[7] The evidence of publication selection bias remains strong for both

[7] We also implement the test proposed by Andrews & Kasy (2019) for these two subsamples—see Appendix 3B. The results are very similar to those obtained for the full sample.

subsamples. The second, alternative, strategy we employ is presented in the following section, in which we account for the observed heterogeneity in estimates by including a number of studies' characteristics as additional controls in regression (3).

3.5 Variation in TEBS estimates

Estimates may vary due to variation in the underlying 'true' elasticity. They may also vary with empirical methods employed by researchers and other features of studies' design. In this section we construct a comprehensive set of explanatory variables to capture key factors likely contributing to the variation in estimates and use meta-regression analysis to determine which study characteristics have systematic effects on the reported TEBS.

3.5.1 Explanatory variables

We describe below the key explanatory variables that capture features of data and techniques used by researches estimating TEBS. The full list of the 29 recorded variables and their descriptive statistics are available in Table 3A.1.

Data characteristics

Tax elasticity of border sales can be estimated with different kinds of data. The majority of studies in our sample use data at the annual frequency. At the same time, a number of studies employ daily data (e.g. Khan *et al.* 2020), weekly data (e.g. Hansen *et al.* 2020), monthly data (e.g. Ye & Kerr 2016), and as well as data at quarterly frequency (e.g. Baranzini & Weber 2013). Similarly, while most studies estimate TEBS with state-level data, some use data at the household or county level (e.g. Lesley & Erich 2008), as well as data on border sales associated with travel across countries (e.g. Friberg *et al.* 2022). Finally, some studies investigating TEBS in the US obtain data from local sources (e.g. Merriman 2010), while others use statistics collected at the federal level (e.g. Stehr 2007). We construct a set of controls to reflect the above differences. We additionally record the number of observations used to obtain each estimate, and the average year of data. As before, we include the standard errors associated with the estimates to capture publication bias.

Economic, geographic & demographic controls and characteristics

Studies evaluating TEBS typically estimate how sales in the home region are affected by the discrepancy between home and neighbor prices. But this difference is not the only factor that could potentially affect sales. The volume of sales in a given region is likely to depend on the economic wellbeing of the underlying population, as well as its demographic composition. We construct a set of variables reflecting whether the authors control for such factors in their analysis. The 'true' TEBS itself may vary across geographic regions. Car travel is much more prevalent and culturally accepted in the US compared to Europe. We construct controls to distinguish between TEBS estimates for the US and other countries.

Consumption data features

Consumers may exhibit different propensities to travel depending on commodities being taxed—the underlying 'true' value of TEBS may thus be different for different commodities. A large number of studies in our sample focuses exclusively on tobacco sales (e.g. Becker *et al.* 1994, Goel & Nelson 2012, and Lakhdar *et al.* 2016); other studies calculate TEBS for fuel (e.g.Leal *et al.* 2009, and Jansen & Jonker 2018), food and retail (Fox 1986, and Wooster & Lehner 2010) and other 'sin' products, such as marijuana, alcohol and soda (e.g. Ye & Kerr 2016, Hansen *et al.* 2020, and Seiler *et al.* 2021). For each TEBS estimate, we record the type of consumer goods it pertains to.

Estimation approaches

The vast majority of studies in our sample estimate TEBS—or effects from which TEBS can be imputed—with OLS (e.g. Apergis *et al.* 2014, and Friberg *et al.* 2022). A number of studies employ alternative methods, such as IV (e.g. Baltagi & Griffin 1995), GLS (e.g. Banfi *et al.* 2005), difference in differences (e.g. Leal *et al.* 2009), probit (e.g. Chernick & Merriman 2013) or other methods (e.g. spatial regression in Tosun & Skidmore 2007, seemingly unrelated regression in Asplund *et al.* 2007, ARIMA in Ye & Kerr 2016). Many studies also employ state and time fixed effects (e.g. Farrelly *et al.* 2003, Seiler *et al.* 2021). We construct a set of controls to account for these differences.

Specification

While many studies in our sample estimate versions of regression (1), their precise definitions of the left- and right-hand side variables may differ. For example, the dependent variable may come in the form of dollar sales (e.g. Ballard & Lee 2007) or sales expressed in quantities (e.g. number of packs of cigarettes purchased, Connelly *et al.* 2009, or volume of gasoline, Banfi *et al.* 2005). A number of studies weight the prices of various neighbors by the size of the population at the respective borders (e.g. Farrelly *et al.* 2003). While some studies in our sample estimate how sales respond to changes in the log price index (as in 2), many measure tax elasticity by estimating the coefficient on the log of the after-tax neighbor price. There are therefore some differences in the interpretation of TEBS estimates produced by the studies—we capture them by constructing corresponding controls.

For some estimates we perform conversions to make them comparable with our baseline specification (i.e. specification 1). A number of studies estimate interactions between sales and distances from the border, obtaining distance-specific TEBS (e.g. Lovenheim 2008). To make these estimates comparable with our baseline that does not include distance, we use information provided by these studies to construct estimates of TEBS conditional on mean distance considered in each paper. Some papers employ log-linear specifications (e.g. DeCicca *et al.* 2013, Lovenheim 2008). We likewise use descriptive statistics included in the papers to convert the provided estimates to a format comparable with our baseline specification. We construct controls to reflect these differences.

Publication characteristics

It is possible that studies in our sample are of differing quality. Even though we control for a number of observable characteristics of the studies and the underlying datasets, it is possible that there are some more subtle features related to study quality that we are missing. To account for the potential unobservable variation in study quality, we construct two additional controls. First, we record whether the study was published in one of the top five general interest journals in economics or in the top field journal for public finance (similar to Sokolova & Sorensen 2021). Second, we record the average yearly number of citations that the study received since its first appearance on Google Scholar (as in e.g. Havranek *et al.* 2015).

3.5.2 Variation in TEBS estimate and model uncertainty

In the previous section we pointed out a large number of study features that could potentially contribute to the observed variation in TEBS estimates. We accordingly constructed 29 associated control variables. We will now employ these controls to pin down the sources of variation in TEBS estimates with meta-regression analysis. We will estimate the following regression model:

$$\hat{\epsilon}_{ij} = \alpha_0 + \sum_{l=1}^{29} \beta_l X_{l,ij} + u_{ij}, \tag{4}$$

where $\hat{\epsilon}_{ij}$ is the i-th estimate of TEBS reported by j-th study, $X_{l,ij}$ are the explanatory variables capturing variation in estimates, and u_{ij} is noise. The estimates of β_l would reflect the contribution of each factor from the set of 29 predictors to variation in elasticity estimates.

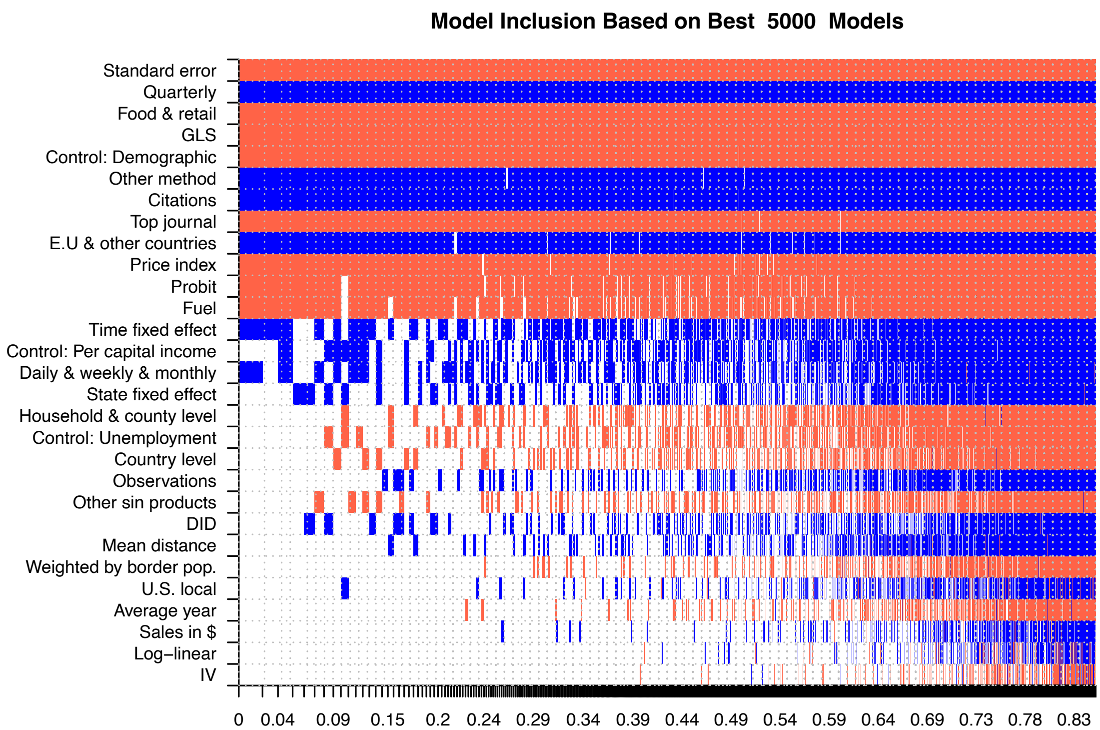
One important caveat to consider while estimating regression (4) is model uncertainty. While it is likely that a subset of the 29 variables we constructed is part of the 'true' data generating process for TEBS estimates, it is probably not true that *every one* of these variables contributes to variation in TEBS estimates in a meaningful way. We thus face the following problem. On the one hand, including all 29 variables in regression (4) would likely render the model misspecified. On the other hand, choosing one smaller subset of the 29 variables would not account for the possibility that some of the remaining $2^{29}-1$ variable combinations could do better at capturing the data generating process for estimates of TEBS.[8]

Fernandez *et al.* (2001) point out the importance of model uncertainty in cross-country growth regressions and argue in favor of a more rigorous approach—the Bayesian Model Averaging (BMA, see Raftery *et al.* 1997). BMA evaluates and compares all of the 2^{29} possible combinations of the explanatory variables, assigning each a metric (posterior model probability, PMP) that measures how likely each model is to represent the underlying data generating process. BMA then constructs inference by averaging results across all evaluated models weighted by the corresponding PMP. BMA has been used in other meta-analyses in contexts similar to ours (e.g. Havranek *et al.* 2017, Balima & Sokolova 2021). Following these studies, we estimate model (4) with BMA.

Figure 3.2 provides graphical representation of the BMA estimation results. Each column on the graph represents one of the 2^{29} combinations of the explanatory variables, i.e. a model. For each model, white coloring means that a given variable is not

[8]In such cases researchers often employ sequential t-testing; however, a sequential exclusion of insignificant regressors could lead to an accidental omission of variables that belong to the data generating process—thus, it does not adequately address the issue of model uncertainty.

Figure 3.2: Bayesian Model Averaging: Models



Notes: The figure depicts the results of BMA estimation of regression (4). Each column gives one model; the models are ranked by their posterior model probability (cumulative PMPs are marked on the horizontal axis). The vertical axis lists explanatory variables ranked by their PIPs. White cell means that the variable on the left-hand-side is not included in the given model; red (blue) means the variable is included and the estimated coefficient is negative (positive). Variable description is available in Table 3A.1. The figure was obtained with the `BMS` package for `R` developed by Zeugner & Feldkircher (2015). We use a combination of the Unit Information Prior for model parameters and the Uniform prior for model space; alternative priors are considered on Figure 3C.2.

included, while red (blue) indicates that the control is included and the corresponding estimated effect is negative (positive). The horizontal axis lists cumulative posterior model probabilities for models depicted, while vertical axis ranks the 29 control variables by their posterior inclusion probabilities (PIP). For each variable, a PIP reflects the likelihood of the variable belonging to the 'true' data generating process for TEBS estimates; it is computed by adding up all PMPs of models in which the variable is present.

The variables listed at the top of Figure 3.2 are the most likely to be part of the 'true' data generating process for TEBS estimates. The signs of the effects associated with these controls are very stable across different models. One such variable is the standard error associated with the TEBS estimates: it is present in all 'good' models depicted on Figure 3.2. We document a strong negative relationship between TEBS estimates $\hat{\epsilon}_{ij}$ and their respective standard errors, $SE(\hat{\epsilon}_{ij})$,—corroborating the findings of Section . We conclude that the evidence of selective reporting of estimates with the 'right sign' remains intact even after we control for other potential sources of observable variation in TEBS.

Table 3.3: Heterogeneity and Model Uncertainty

	BMA			OLS	
Response variable:	Post. Mean	Post. SD	PIP	Coef.	SE
Data Characteristics					
Standard error	-0.256	0.038	1.000	-0.296	0.066
Observations	0.015	0.030	0.257		
Average year	-0.016	0.062	0.096		
Daily & weekly & monthly	0.250	0.307	0.473		
Quarterly	2.047	0.371	1.000	1.979	0.690
Household & county level	-0.181	0.294	0.336		
Country level	-0.139	0.265	0.265		
U.S local	0.061	0.208	0.122		
Economic, geographic & demographic controls					
Control: Per capita income	0.175	0.200	0.504	0.130	0.170
Control: Unemployment	-0.129	0.210	0.325		
Control: Demographic	-0.585	0.130	0.992	-0.687	0.281
E.U. & other countries	0.773	0.274	0.962	0.936	0.353
Consumption data features					
Food & retail	-1.993	0.273	1.000	-1.973	0.944
Fuel	-0.706	0.411	0.825	-0.805	0.454
Other sin products	-0.107	0.209	0.256		
Estimation approaches					
GLS	-0.623	0.186	0.996	-0.620	0.498
DID	0.122	0.249	0.237		
IV	-0.002	0.024	0.026		
Probit	-0.883	0.418	0.904	-0.860	0.745
Other method	0.723	0.219	0.988	0.601	0.427
State fixed effect	0.102	0.161	0.340		
Time fixed effect	0.228	0.215	0.609	0.318	0.169
Specifications					
Sales in $	0.015	0.085	0.057		
Weighted by border pop.	-0.041	0.127	0.128		
Price index	-0.589	0.220	0.944	-0.592	0.453
Mean distance	0.098	0.213	0.218		
Log-linear	0.003	0.045	0.030		
Publication characteristics					
Top journal	-1.109	0.346	0.981	-1.035	0.508
Citations	0.192	0.052	0.984	0.195	0.090
Constant	-0.349		1.000	-0.182	0.195
Studies	60			60	

Continued on next page

Table 3.3: Heterogeneity and model uncertainty: BMA

Response variable:	Post. Mean	Post. SD	PIP	Coef.	SE
Observations	749			749	

Notes: The left panel of the table reports numerical results of BMA estimation corresponding to Figure 3.2. 'SD' is standard deviation; 'PIP' is posterior inclusion probability; 'SE' is standard error. The right panel reports results from an OLS estimation of a specification in which we only include variables with PIP higher than 50%. Standard errors are clustered at the study level.

Among other variables with high PIPs are controls reflecting the types of products the elasticity is estimated for and their geographic region. It appears that, compared to tobacco, the sales of fuel, food and retail are more elastic with respect to changes in relative price. This means that consumers are more likely to take advantage of cross-border price differences when shopping for these goods—relative to tobacco. At the same time, TEBS estimates of other 'sin' products do not seem to differ very much from those for tobacco. Furthermore, US consumers appear to be more engaged in cross-border shopping compared to consumers living in Europe and other countries. This may be due to the prevalence of 'car culture' in the US and its overall greater reliance on personal transportation.

We also observe that sales appear more elastic when TEBS is estimated on annual data—particularly compared to datasets of quarterly frequency. This difference may reflect the fact that it takes time for consumers to notice the price difference between regions and change their shopping behavior. The difference between annual and high frequency data (monthly or higher) has a similar direction, though it appears less statistically prominent—possibly due to limitations of our data.

Finally, we document some differences in TEBS estimates that arise due to differences in studies' design, such as the use of GLS and some other estimation methods. We also find that studies published in top journals tend to report more prominent TEBS estimates compared to studies published in other outlets; however, studies that accumulate greater numbers of citations per year tend to report more modest effects.

The left panel of Table 3.3 summarizes the numerical results from the BMA estimation. The right panel of Table 3.3 reports results from the 'frequentist check', in which we run an OLS with only the variables that showed PIP higher than 50% in the BMA—that is, the variables that were deemed likely to be part of the 'true' data generating process for TEBS estimates.

Sales of food and retail appear substantially more elastic than those of tobacco: when the price difference increases by one percentage point, these sales fall by about 2 percentage points more compared to tobacco sales. Unlike purchases of individual 'sin' products, spending on food and retail typically amounts to a large fraction of household budget—potential savings from shopping at a jurisdiction with a lower sales tax may thus justify the travel costs. In a similar vein, sales of fuel are more responsive to changes in regional price differences compared to sales of tobacco. A one percentage point increase in the price difference leads to a 0.7-0.8 percentage point decrease in fuel sales. Unlike all other goods, fuel consumption is directly related to the act of traveling by personal transport. Furthermore, fuel prices are typically very clearly displayed at gas station entrances, and are easily noticed and compared by those shopping for gas. All of these considerations may make consumers more responsive to changes in the prices of fuel. At the same time, the difference between TEBS for tobacco and other sin goods (alcohol, soda, marijuana) is not prominent, nor statistically significant. Thus, we can conclude that the sales elasticities of individual 'sin' goods (excluding fuel) are relatively similar.

Aside from differences across goods, we document a prominent discrepancy between TEBS estimates across geographic regions. TEBS estimates for the US are lower than those for Europe and other countries by about 0.8-0.9 percentage points, making US sales considerably more elastic.

The negative coefficient on the standard errors associated with TEBS estimates remains statistically significant—even after we control for an extensive list of features of study design that may cause estimates to vary systematically across studies. This corroborates the conclusions of the previous section, suggesting that publication selection bias is indeed prominent in the literature on TEBS.

We next examine the extent to which these results may be driven by outliers in the data. As in Section , we consider four outlier treatments: samples with outliers in estimates and standard errors winsorized at 1% and 5%, as well as samples in which 1%(5%) of outliers are dropped—see Figure 3C.1. None of the outlier treatments affect the inference made about the standard error, suggesting that the evidence of selective reporting we find is not driven by the outliers in the data. At the same time, the difference between TEBS for tobacco on the one hand, and food and retail as well as fuel on the other, seems to be affected by the strong outlier treatments (winsorization at 5% and dropping 5% of outliers). Similarly, the strong outlier treatments affect the inference about TEBS for Europe and other countries.

We turn to study the extent to which our BMA results may be driven by the prior assumptions made about the model parameters and the model space. In our baseline specification, we employ the unit information prior (UIP) for parameters—that is, a prior that communicates the amount of information similar to that of one observation; for model space, we use the uniform prior. This combination of priors was found to work well for predictive estimations (Eicher *et al.* 2011). Figure 3C.2 compares our baseline results to those obtained under alternative combinations of priors. For parameters, we consider benchmark g-priors ('BRIC' on Figure 3C.2, see Fernández *et al.* 2001) and the flexible data-dependent priors ('HyperBRIC' on Figure 3C.2, see Liang *et al.* 2008). For model space, we introduce the beta-binomial model prior ('Random' on Figure 3C.2, see Ley & Steel 2009). We find that these alternative prior assumptions do not have much of an effect on the posterior means—albeit they tend to result in higher posterior inclusion probabilities for most of our explanatory variables.

Finally, we employ LASSO—an alternative approach to addressing model uncertainty (see Tibshirani 1996). This procedure runs an OLS minimization subject to a constraint on the sum of the absolute values of model coefficients. Because of the constraint, the minimization yields corner solutions, setting some of the model coefficients to exact zeros. For our dataset, LASSO does not exclude any of the variables (see Table 3C.1). The post-LASSO OLS estimation indicates that the standard error is still statistically significant, even despite the presence of 28 other explanatory variables in the regression. The other variables that show significance in the BMA—such as the effects associated with fuel, food retail—have coefficients that in magnitude and direction are similar to those obtained before, albeit not statistically significant.

3.5.3 Bias-corrected estimates

We will now consider the implications of these results for the magnitudes of TEBS estimates. Using the OLS specification from Table 3.3, we construct fitted estimates of TEBS for different groups of consumer goods and geographic regions—conditional on correcting for publication bias. Panel A of Table 3.4 reports bias-corrected point estimates of TEBS, obtained by substituting sample means for all variables except the standard error and the corresponding group variable. The overall point estimate of -0.411 has similar interpretation as the constant term in Table 3.2: it is the overall bias-corrected estimate of TEBS; as before, this estimate is smaller in magnitude compared to the mean TEBS reported by the literature—because it is corrected for selective reporting.

At the same time, fitted TEBS estimates differ depending on the consumption group and the geographic region considered. Sales of food and retail appear to be the most elastic, with TEBS of about -2; sales of fuel are elastic as well (TEBS of -0.87). Tobacco sales and sales of other 'sin' products appear much less elastic: the point estimate is small in magnitude and its confidence interval includes zero. There are also prominent geographic differences in overall estimated effects. While for the US, TEBS is negative and prominent, it is not so for EU and other countries: for these regions, once we account for selective reporting, the effect becomes statistically indistinguishable from zero.

We additionally compute TEBS estimates that are conditional on 'best practice' in the literature: for this exercise, we substitute 1 for *Top journal* and the value of the 90th percentile for *Citations* (as well as, again, correcting for publication bias). This

Table 3.4: Fitted Estimates by Group

Panel A: Fitted estimates with bias correction		
	Point Estimate	95% interval
All	-0.411	[-0.534 ; -0.287]
Product groups		
Food & retail	-2.042	[-3.628; -0.455]
Fuel	-0.873	[-1.532; -0.215]
Tobacco and other sin products	-0.068	[-0.359; 0.223]
Regions		
U.S.	-0.617	[-0.848; -0.385]
E.U. & other countries	0.319	[-0.183; 0.821]
Panel B: 'Best practice' estimates with bias correction		
	Point Estimate	95% interval
All	-0.978	[-1.971; 0.015]
Product groups		
Food & retail	-2.609	[-4.858; -0.360]
Fuel	-1.441	[-2.817; -0.065]
Tobacco and other sin products	-0.636	[-1.484; 0.212]
Regions		
U.S.	-1.184	[-2.212; -0.156]
E.U. & other countries	-0.249	[-1.302; 0.805]

Notes: Here we report fitted values of TEBS obtained using estimation results of the frequentist check reported in the right panel of Table 3.3. For both panels, to compute the estimates and the confidence intervals, we substitute zeros for standard errors—to correct for publication bias. In panel B we additionally substitute the values of the 90th percentile for the citations and one for 'top journal'.

is done in an attempt to give higher weight to studies of potentially higher quality. As we show in Panel B of Table 3.4, TEBS estimates that are widely cited and published in top journals tend to be greater in magnitude compared to the estimates reported by the literature overall—at least according to the corresponding point estimates.

Overall, even when the publication bias is accounted for, the literature still suggests that consumers engage in the cross-border shopping behavior—particularly where fuel, food and retail purchases are concerned. At the same time, sales of tobacco and other individual 'sin' products appear less elastic: with the exception of fuel, consumers may be less likely to travel across jurisdictions to take advantage of the price differences for individual 'sin' goods.

3.6 Conclusion

We conduct the first meta-analysis of the literature estimating tax elasticity of border sales, collecting 749 estimates from 60 studies in this field. We demonstrate that the literature is prone to systematic underreporting of positive estimates, which gives rise to a bias in the mean reported TEBS estimate that exaggerates the elasticity of sales at the border. We provide appropriate bias corrections.

We find that cross-border sales of food, retail and fuel are much more elastic to changes in tax rates compared to sales of tobacco and other 'sin' products. Sales tax has a broader base compared to excise taxes. Spending on food and retail constitutes a large fraction of household budget—changes in the local sales tax may prompt households to seek opportunities to save by shopping across the border. Compared to food and retail, household spending on fuel may be smaller. However, unlike other goods, fuel consumption is itself associated with travel; furthermore, gas stations tend to prominently display the associated fuel prices, facilitating cross-border comparisons for travelers—these considerations may explain the associated high elasticity of border sales for fuel.

Our meta-analysis shows that there is cross-border shopping behavior that may affect the stability of profits from sales and excise taxes, as well as the intended use of the latter as Pigouvian instruments aimed at reducing consumption of the 'sin' products. In particular, we find that cross-border shopping is prevalent in the US, possibly due to the wide-spread emphasis on personal transportation. At the same time, once publication selection bias is accounted for, TEBS for Europe and other countries becomes statistically indistinguishable from zero, and TEBS for the US becomes somewhat less prominent.

Our meta-analysis provides future researchers with a comprehensive framework for comparing their estimates to those reported in the existing literature. Our findings may be particularly beneficial for the discussions that emerged in recent years, of the new types of excise taxes—taxes on sugar, marijuana and fat—and of the interjurisdictional tax differences coming from sales tax holidays and other tax relief measures by state and local governments. In the future, many states may expand their sales tax base to include more services, which could also create differences in the tax systems of neighboring jurisdictions and trigger more cross-border shopping.

We believe that there will be many more studies of TEBS in the coming years: studies that will focus on the new types of taxes and address the sharp changes in cross-border shopping patterns prompted by the COVID-19 pandemic.

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Appendix 3A Description of Variables

Table 3A.1: Definitions and Summary Statistics of Explanatory Variables.

Variable	Description	Mean (all)	Std. dev (all)
Data characteristics			
Standard error	= standard error of the TEBS estimate.	0.536	1.264
Observations	= log number of observations in the dataset.	7.318	2.019
Average year	= the log of midyear of data used minus 1961, i.e. the earliest midyear in our sample.	3.288	0.746
Daily & weekly & monthly	= 1 if the frequency of the data used is daily, weekly or monthly (baseline: frequency is annual).	0.210	0.407
Quarterly	= 1 if the frequency of the data used is quarterly (baseline: frequency is annual).	0.075	0.263
Household & county level	= 1 if estimated at a household or county level, or at a region level of size comparable to a county (baseline: state level).	0.144	0.352
Country level	= 1 if estimated at a country level (baseline: state level).	0.117	0.322
U.S. local	= 1 if data is taken from a U.S. state or local source.	0.148	0.356
Economic, geographic & demographic controls			
Control: Per capita income	= 1 if per capita personal income is included in regression.	0.712	0.453
Control: Unemployment	= 1 if unemployment rate is included in regression.	0.089	0.286
Control: Demographic	= 1 if age and/or race are controlled for.	0.272	0.445
E.U. & other countries	= 1 if data comes from Europe, or other countries excluding the US (baseline: data from the US).	0.220	0.415
Consumption data features			
Food & retail	= 1 if estimate corresponds to food or retail (baseline: tobacco).	0.126	0.332
Fuel	= 1 if estimate corresponds to fuel (baseline: tobacco).	0.117	0.322
Other sin products	= 1 if estimate corresponds to other 'sin' products, i.e. marijuana, alcohol or soda (baseline: tobacco).	0.109	0.312
Estimation approaches			
GLS	= 1 if GLS or FGLS is employed (baseline: OLS).	0.077	0.267
DID	= 1 if Difference in Differences method is employed (baseline: OLS).	0.063	0.243
IV	= 1 if IV method is employed (baseline: OLS).	0.097	0.297

Continued on next page

Table 3A.1: Definitions and summary statistics of explanatory variables (continued)

Variable	Description	Mean (all)	SD (all)
Probit	= 1 if Probit is employed (baseline: OLS).	0.049	0.217
Other method	= 1 if other method is employed, e.g. Spatial, Semi-structual, ARIMA (baseline: OLS).	0.056	0.230
State fixed effect	= 1 if state fixed effects are included.	0.497	0.500
Time fixed effect	= 1 if time fixed effects are included.	0.247	0.432
Specifications			
Sales in $	= 1 if the dependent variable is sales measured in dollars/local currency (baseline: sales measured as quantity).	0.203	0.402
Weighted by border pop.	= 1 if neighbor prices are weighted by the size of the respective border population.	0.077	0.267
Price index	= 1 if elasticity reflects the response to changes in the relative price index as in (2) (baseline: elasticity reflects response to changes in neighbor price).	0.414	0.493
Mean distance	= 1 if regression includes interaction of neighbor price (price index) with distance. In such cases we obtain the estimate comparable to the rest of the sample by calculating elasticity assuming mean distance considered in the paper.	0.134	0.340
Log-linear	= 1 if the model is log-linear.	0.072	0.259
Publication characteristics			
Top journal	= 1 if the study was published in one of the top five general interest journals in economics or the top field journal in public fiance.	0.025	0.157
Citations	= log value of citations per year since the paper first appeared on Google Scholar.	0.534	1.635
Numbers of studies	60		
Observations	749		

Notes: We report means and standard deviations for the full sample of 749 observations. When indicator variables form groups, we state the reference category.

Appendix 3B Publication Bias: Additional Results

Appendix 3B.1 Outlier treatments

Table 3B.1: Testing for Publication Bias

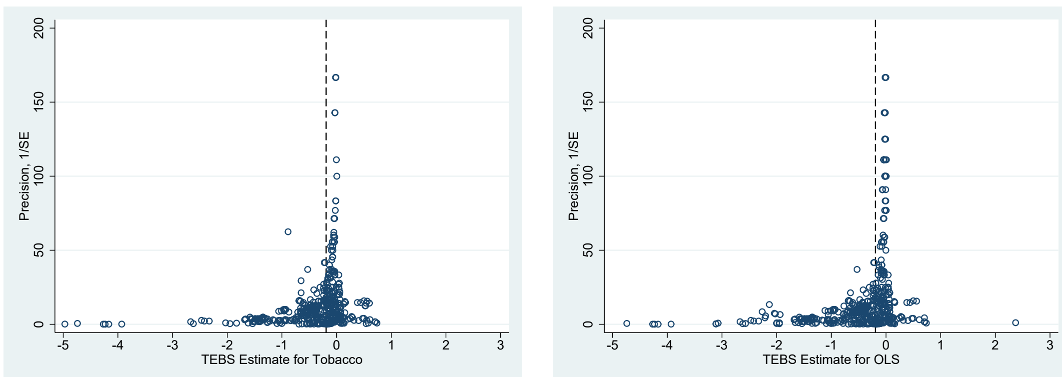
	OLS	FE	BE	Precision	Study
Winsorized at 1%					
SE dummy	-0.330	-0.314	-0.681	-1.004	-0.782
	(0.121)	(0.092)	(0.174)	(0.331)	(0.332)
Constant	-0.395	-0.403	-0.509	-0.038	-0.485
	(0.093)	(0.049)	(0.251)	(0.017)	(0.204)
Studies	60	60	60	60	60
Observations	749	749	60	749	749
Winsorized at 5%					
	OLS	FE	BE	Precision	Study
SE dummy	-0.483	-0.503	-0.942	-1.028	-0.986
	(0.204)	(0.166)	(0.122)	(0.306)	(0.128)
Constant	-0.291	-0.282	-0.198	-0.045	-0.209
	(0.083)	(0.075)	(0.132)	(0.019)	(0.083)
Studies	60	60	60	60	60
Observations	749	749	60	749	749
Dropped 1%					
	OLS	FE	BE	Precision	Study
SE dummy	-0.294	-0.307	-0.679	-0.955	-0.733
	(0.096)	(0.083)	(0.169)	(0.315)	(0.331)
Constant	-0.386	-0.379	-0.510	-0.035	-0.516
	(0.087)	(0.044)	(0.243)	(0.015)	(0.203)
Studies	60	60	60	60	60
Observations	743	743	60	743	743
Dropped 5%					
	OLS	FE	BE	Precision	Study
SE dummy	-0.195	-0.239	-0.190	-0.831	-0.329
	(0.059)	(0.053)	(0.071)	(0.299)	(0.122)
Constant	-0.345	-0.324	-0.351	-0.036	-0.337
	(0.074)	(0.026)	(0.089)	(0.016)	(0.066)
Studies	54	54	54	54	54
Observations	714	714	54	714	714

Notes: This table checks the robustness of the results presented in Table 3.2 against the treatment of outliers. *Winsorized at 1%*= sample with outliers in each tail winsorized at 0.5%; *Winsorized at 5%*= sample with outliers in each tail winsorized at 2.5%; *Dropped 1%*= sample with 1% of outliers dropped; *Dropped 5%*= sample with 5% of outliers dropped. See also notes for Table 3.2.

Appendix 3B.2 Homogenous subsamples

Figure 3B.1: Funnel Plots.
Homogenous Subsamples

(a) *Tobacco* only (b) *OLS* only



Notes: Figure 3B.1(a) plots TEBS estimates for Tobacco against their precision; Figure 3B.1(b) plots TEBS estimates obtained using OLS against their precision; the dashed lines indicate respective sample means. The figures are truncated at $1/SE = 200$.

Appendix 3B.3 Publication bias using Andrews & Kasy 2019

In this section we use the method designed by Andrews & Kasy 2019 (AK2019) to model selective reporting, estimate publication probabilities depending on the sign and significance of the results, and obtain the corrected 'unbiased' estimate implied by this model.

The AK2019 model we use assumes the following structure. The 'true' underlying elasticities vary across studies—for each latent study j, the corresponding underlying effect ϵ_j is drawn from a distribution (e.g. a t-distribution); the mean of this distribution, $\bar{\epsilon}$, is unknown, but will be estimated later—the estimate of $\bar{\epsilon}$ will be interpreted as the bias-corrected 'true' elasticity. The study j then generates estimates ϵ_{ij} that are drawn from a normal distribution with ϵ_j as a mean. Some of these estimates will be reported; the probability of reporting, p(Z), depends on the value of the estimates divided by their standard errors, Z.

In this paper we estimate the version of the AK2019 model discussed in Section IIIC of the body of their paper. Following the authors, we assume that the 'true' elasticity ϵ_j for each latent study j comes from a t-distribution with mean $\bar{\epsilon}$, $\bar{v}$ degrees

Table 3B.2: Testing for Publication Bias:
Homogenous Subsamples

	OLS	FE	BE	Precision	Study
Panel A: Tobacco only					
SE	-0.204	-0.287	-0.030	-0.694	-0.233
	(0.057)	(0.080)	(0.050)	(0.329)	(0.026)
Constant	-0.318	-0.272	-0.331	-0.045	-0.313
	(0.099)	(0.045)	(0.070)	(0.025)	(0.063)
Studies	35	35	35	35	35
Observations	485	485	35	485	485
Panel B: OLS only					
	OLS	FE	BE	Precision	Study
SE	-0.244	-0.252	-0.607	-0.773	-0.670
	(0.072)	(0.052)	(0.139)	(0.331)	(0.310)
Constant	-0.366	-0.361	-0.329	-0.045	-0.386
	(0.101)	(0.032)	(0.224)	(0.027)	(0.171)
Studies	46	46	46	46	46
Observations	492	492	46	492	492

Notes: Panel A considers a subset of TEBS estimates that refer to Tobacco. Panel B considers a subset of TEBS estimates obtained using OLS. See also notes for Table 3.2.

of freedom and a scale parameter $\tilde{\tau}$. For each result, the probability of it being reported is encompassed by the following step function:

$$p(Z) \propto \begin{cases} \beta_{\mathrm{p},1} \text{ if } Z > 1.96, \\ \beta_{\mathrm{p},2} \text{ if } 0 < Z \leq 1.96, \\ \beta_{\mathrm{p},3} \text{ if } -1.96 < Z \leq 0, \\ 1 \text{ if } Z \leq -1.96. \end{cases} \tag{5}$$

Here, we normalize probability of reporting a negative result significant at the 5% level to 1 and use maximum likelihood to estimate the relative reporting probabilities for negative and positive insignificant results ($\beta_{\mathrm{p},3}$ and $\beta_{\mathrm{p},2}$), and for positive results significant at the 5% level ($\beta_{\mathrm{p},1}$).

The estimation results are reported in Table 3B.3. We find the probability of reporting a positive result to be dramatically lower compared to a result that is negative and significant: a positive estimate is about 18 times less likely to be reported. A negative insignificant result is about seven times less likely to be reported compared to a result with a Z-score below -1.96. The estimate of $\bar{\epsilon}$, the mean 'true' elasticity, is very close to zero and positive. Thus, overall, the AK2019 test indicates even more selective reporting compared to the tests examined in Section .

Table 3B.3: Testing for Publication Bias Using Andrews & Kasy 2019

$\bar{\epsilon}$	$\tilde{\tau}$	$\tilde{\nu}$	$\beta_{p,1}$	$\beta_{p,2}$	$\beta_{p,3}$
0.014	0.066	1.561	0.055	0.055	0.144
(0.006)	(0.020)	(0.135)	(0.025)	(0.018)	(0.041)

Notes: Standard errors appearing in parenthesis are clustered at the study level. The results are obtained using the `Matlab` code for AK2019 that replicates their Table 3.

As discussed in the body of the paper, one caveat associated with the AK2019 model is that the estimates examined need to be relatively homogenous—otherwise the assumptions about the distributions of 'true' elasticities and the estimates produced by studies might not be appropriate. To check the robustness of our findings, we consider two subsamples of our data that are more homogenous: a subsample of estimates pertaining to sales of tobacco, and a subsample of estimates obtained through OLS. The results are reported in Table 3B.4. The results are similar to those for the baseline sample, albeit the underlying 'true' effect is found to be negative for the OLS estimates. For the subsample of OLS estimates, the TEBS of -0.004 is statistically different from zero—but not for tobacco.

Table 3B.4: Testing for Publication Bias Using Andrews & Kasy (2019): Homogenous Subsamples

Panel A: Tobacco only					
$\bar{\epsilon}$	$\tilde{\tau}$	$\tilde{\nu}$	$\beta_{p,1}$	$\beta_{p,2}$	$\beta_{p,3}$
0.005	0.091	1.218	0.046	0.077	0.191
(0.009)	(0.056)	(0.310)	(0.027)	(0.031)	(0.065)
Panel B: OLS only					
$\bar{\epsilon}$	$\tilde{\tau}$	$\tilde{\nu}$	$\beta_{p,1}$	$\beta_{p,2}$	$\beta_{p,3}$
-0.004	0.038	0.750	0.048	0.072	0.214
(0.001)	(0.020)	(0.119)	(0.029)	(0.034)	(0.082)

Notes: Standard errors appearing in parenthesis are clustered at the study level. The results are obtained using the `Matlab` code for AK2019 that replicates their Table 3. Panel A considers a subset of TEBS estimates that refer to Tobacco. Panel B considers a subset of TEBS estimates obtained using OLS

Appendix 3C Why do estimates vary? Additional results

Appendix 3C.1 Robustness

Table 3C.1: Why Do Estimates of TEBS Vary? LASSO

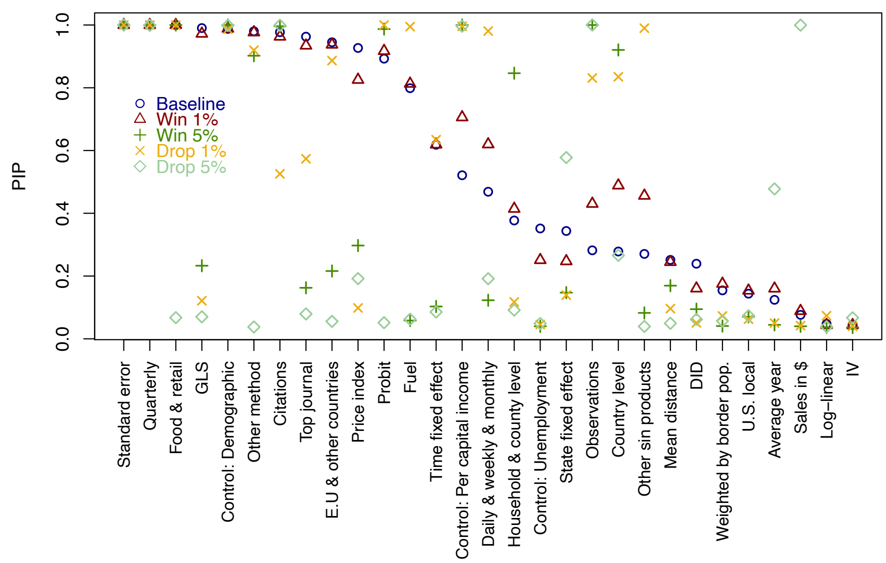
	LASSO	OLS using selected variables	
Response variable	Coef.	Coef.	SE
Data characteristics			
Standard error	-0.235	-0.236	0.067
Observations	0.044	0.046	0.070
Average year	-0.163	-0.174	0.224
Daily & weekly & monthly	0.292	0.315	0.696
Quarterly	1.662	1.696	0.968
Household & county level	-0.584	-0.581	0.542
Country level	-0.566	-0.610	0.470
U.S local	0.279	0.307	0.523
Economic, geographic & demographic controls			
Control: Per capita income	0.460	0.482	0.202
Control: Unemployment	-0.412	-0.412	0.507
Control: Demographic	-0.456	-0.462	0.236
E.U. & other countries	0.793	0.854	0.357
Consumption data features			
Food & Retail	-2.226	-2.297	1.178
Fuel	-0.705	-0.783	0.664
Other sin products	-0.371	-0.414	0.617
Estimation approaches			
GLS	-0.802	-0.828	0.684
DID	0.331	0.365	0.443
IV	-0.077	-0.085	0.163
Probit	-0.843	-0.876	1.164
Other method	0.836	0.866	0.452
State fixed effect	0.128	0.137	0.333
Time fixed effect	0.399	0.400	0.240

Specifications			
Sale in $	0.130	0.156	0.701
Weighted border pop.	-0.385	-0.406	0.331
Price index	-0.384	-0.389	0.362
Mean distance	0.426	0.422	0.361
Log-linear	0.105	0.096	0.504
Publication characteristics			
Top journal	-0.994	-1.050	0.740
Citations	0.134	0.135	0.105
Const.	-0.313	-0.302	0.867
Observations	749	749	.

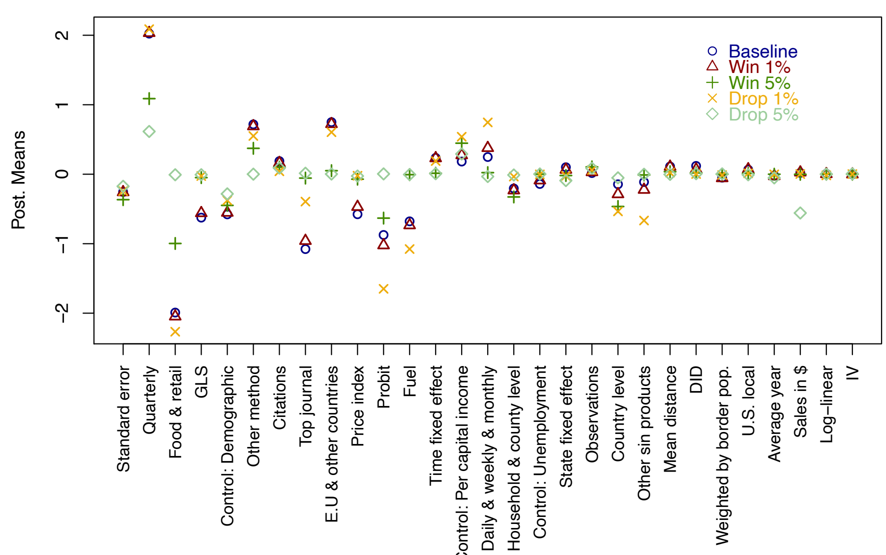
Notes: The left panel presents estimates obtained using LASSO with the penalty set to minimize mean-squared prediction error with cross-validation. We implement this in `STATA` with the `cvlasso` routine. The right panel shows results of estimating OLS using the subset of variables selected by LASSO.

Figure 3C.1: Outlier Treatments

(a) PIP



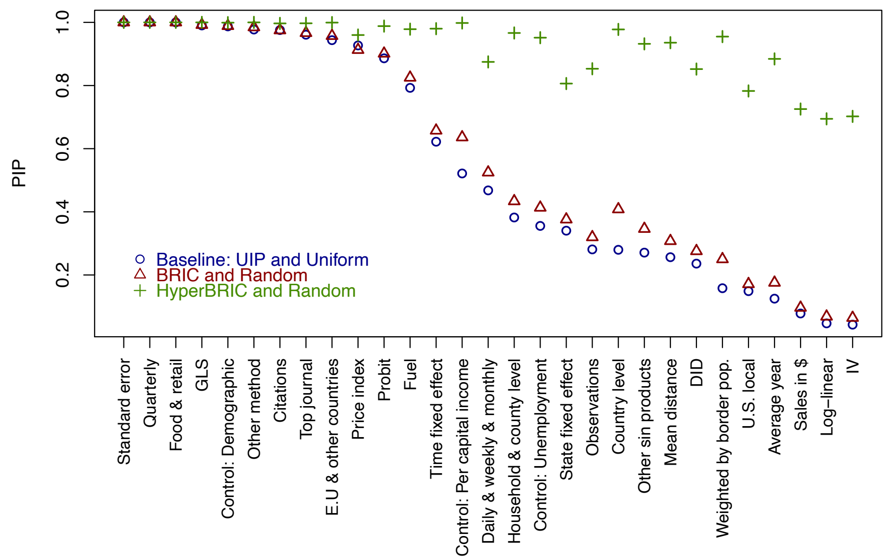
(b) Posterior means



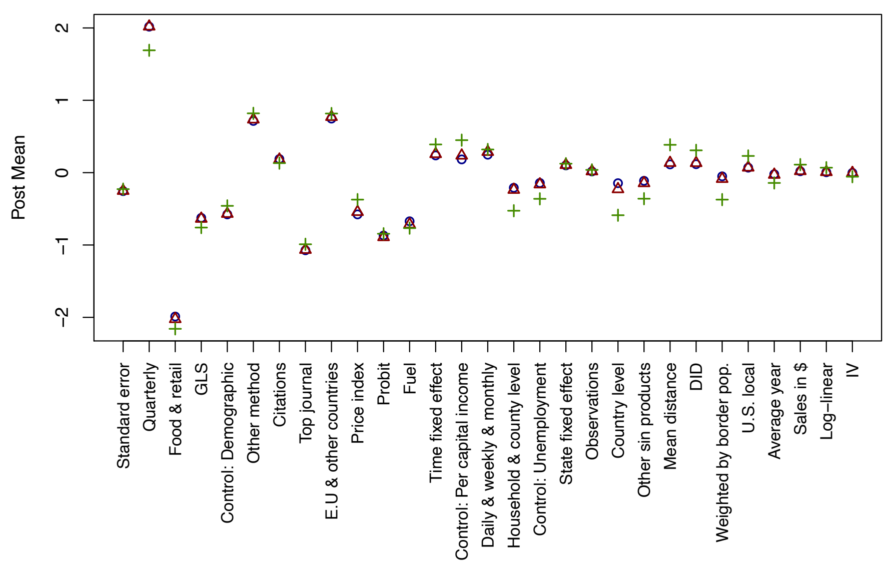
Notes: This figure compares BMA results under alternative outlier treatments. *Winsorized at 1%*= sample with outliers in each tail winsorized at 0.5%; *Winsorized at 5%*= sample with outliers in each tail winsorized at 2.5%; *Dropped 1%*= sample with 1% of outliers dropped; *Dropped 5%*= sample with 5% of outliers dropped.

Figure 3C.2: Priors

(c) PIP



(d) Posterior means



Notes: This figure compares BMA results under alternative assumptions about priors. *UIP*=Unit information prior for model parameters; *Uniform*=Uniform prior for model space; *'BRIC'* = Benchmark g-priors for parameters, see Fernández *et al.* (2001); *'HyperBRIC'*=Flexible data-dependent priors for parameters, see Liang *et al.* (2008); *'Random'*=Beta-binomial prior for model space, see Ley & Steel (2009).

Appendix 3D Studies Used in Meta-analysis

We used the following search query to find the relevant studies:

> Our search query contains the words 'relative price', 'tax difference elasticity estimate border', 'cross-border', "cross-border", 'neighboring sales', 'tax', 'shopping', 'purchases', and 'estimates' save the Google Scholar search results on April 30th, 2021. We read through abstracts of papers appearing on the first 50 pages, download and save papers that appear to report relevant results.
>
> We then read through the downloaded papers making sure they contain estimates of TEBS, or results that could be used to derive the implied TEBS estimates, using conversions discussed in the previous section. We include papers published in peer-reviewed journals, and working papers that came out after the year 2018.
>
> This search strategy yielded 60 studies providing 749 estimates. These estimates cover a diverse set of geographic regions and types of sales.

Papers in the Study

Apergis, N., R. Goel, & J. Payne (2014): "Dynamics of U.S. State Cigarette Consumption: Evidence from Panel Error Correction Modeling." *Atlantic Economic Journal* **42(1)**: pp. 3–20.

Asplund, M., R. Friberg, & F. Wilander (2007): "Demand and Distance: Evidence on Cross-border Shopping." *Journal of public Economics* **91(1-2)**: pp. 141–157.

Ballard, C. L. & J. Lee (2007): "Internet Purchases, Cross-Border Shopping, and Sales Taxes." *National Tax Journal* **60(4)**: pp. 711–725.

Baltagi, B. H. & J. M. Griffin (1995): "A Dynamic Demand Model for Liquor: the Case for Pooling." *The Review of Economics and Statistics* **77(3)**: pp. 545–554.

Baltagi, B. H., J. M. Griffin, & W. Xiong (2000): "To Pool Or Not To Pool: Homogeneous Versus Hetergeneous Estimations Applied to Cigarette Demand." *The Review of Economics and Statistics* **82(1)**: pp. 117–126.

Baltagi, B. H. & D. Levin (1986): "Estimating dynamic demand for cigarettes using panel data: the effects of bootlegging, taxation and advertising reconsidered." *The Review of Economics and Statistics* pp. 148–155.

Baltagi, B. H. & D. Levin (1992): "Cigarette Taxation: Raising Revenues and Reducing Consumption." *Structural Change and Economic Dynamics* **3(2)**: pp. 321–335.

Banfi, S., M. Filippini, & L. C. Hunt (2005): "Fuel tourism in border regions: the case of switzerland." *Energy Economics* **27(5)**: pp. 689–707.

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